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The Roman Construction Process: Building the Basilica of Maxentius

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The Roman Construction Process:

Building the Basilica of Maxentius

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in Architecture

by

Brian Howard Sahotsky

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ABSTRACT OF THE DISSERTATION

The Roman Construction Process:

Building the Basilica of Maxentius

by

Brian Howard Sahotsky

Doctor of Philosophy in Architecture

University of California, Los Angeles, 2016

Professor Diane G. Favro, Chair

In the early 4th century C.E., the interior hall of the Basilica of Maxentius was adorned with eight giant marble monoliths. To reach the building site, the 15-meter, 100-ton columns were shipped 2400 kilometers across the Mediterranean, dragged up the Tiber River, unloaded in the overflowing marble yards, paraded down several kilometers of Roman streets, and erected in an area the size of a football field. In Imperial Rome, the ability to transport massive stone monoliths down narrow cobbled streets or mobilize an entire brick-making industry within a matter of weeks were paramount to the success of large-scale building projects. The construction process required a cooperation between the entire city and its infrastructural material and labor networks. The Roman construction site must have been absolutely symbiotic with its urban environment, especially within the context of the Late Empire. The area immediately surrounding the Forum Romanum was a dense residential and commercial zone characterized by

a complicated topography and a stratified array of architectural monuments. In order to construct any project within the confines of this region, the builders had to balance a poly-modal understanding of technical engineering knowledge with an exceedingly efficient organizing framework. In addition to the organization of the site, the builders had to coordinate with the many disparate types of materials that were constantly arriving from far-flung sources. The scene created by the shouting workmen, the screeching pulleys, and the rumbling streets was undoubtedly among Rome's most interesting spectacles. This dissertation will combine an understanding of the spatial implications of the Roman building site with an awareness of the socio-cultural milieu and the symbiotic relationship between the construction process and its contextual environment.

The dissertation of Brian Howard Sahotsky is approved.

Dana Cuff

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Diane G. Favro, Committee Chair

University of California, Los Angeles

2016

To everyone that never gave up on me.

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Acknowledgements

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1. The Construction Process: Monumental Building's Symbiotic Relationship With Rome

1.1. Introduction and a new theory for understanding the construction process in Rome

Large-scale construction is logistically demanding, and each new challenge is magnified with respect to fluctuating urban conditions. New building projects in Imperial Rome were confronted with rigid site confines, difficult topographical contours, and daunting levels of population density. The urban landscape of Rome endured nearly-continuous change, and the process of construction was a consistent visual element in the city. Each new structure employed a multi-faceted process which was both particular to individual construction needs and reliant on an extant infrastructural framework. The process of constructing a building was, by nature, directly relational to the immediate contextual environment.[1] The relationship cultivated between the two fundamental conditions of process and environment must then be considered as symbiotic. In employing the tenets of a mutual symbiotic relationship, I will explore the complementary roles of nesting and hosting that are performed in order to produce a monumental Roman urban structure.[2]

The antecedent macroscopic view of Roman architecture presents the creative endeavor of construction without the physical process of creation, and overlooks the tacit relationships and

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[1] The pattern of contextual and relational study of Roman buildings, as opposed to analysis based explicitly on archeological information, was pioneered in the field by Brown *Roman Architecture*, Braziller, 1965, MacDonald *The Architecture of the Roman Empire, Volume I: An Introductory Study*, New Haven: Yale University Press, 1982, and MacDonald *The Architecture of the Roman Empire*, *Volume II: An Urban Appraisal*, New Haven: Yale University Press, 1986. Prior to these seminal studies, most compendia of Roman architecture grouped monuments by style or location, and paid little attention to urban context and integrated design process. Even these studies were more interested in the final architectural product, rather than emphasizing a work under construction.

[2] The possibilities for examining the strictly relational aspects of construction have been limited until recently in architectural and archaeological scholarship. Most texts have analyzed buildings in their finished state, or introduced construction techniques independent of correlated processes. Examples of this type include the architectural history text Moffett, Fazio, and Wodehouse *Buildings Across Time: An Introduction to World Architecture*, Boston: McGraw Hill, 2004, and the architectural theory text Mallgrave *Modern Architectural Theory*, Cambridge: Cambridge University Press, 2005. This is also true for the most part in early Roman architectural histories such as Ward-Perkins *Roman Imperial Architecture*, New Haven: Yale University Press, 1994 (orig. 1970), in which the author discusses siting and construction types (brick-faced concrete, stone, wattle-and-daub), but is not interested in the actual context and experience of each structure's process of construction.

logistical minutiae of each project. The only Roman primary sources concerning architecture recorded prescriptive information for the manufacture of structures and implements, but provided no account of the actual processes that shape monuments and dictate their appearance.[3] There were requisite procedures for raising each marble column and spanning each timber roof, but we are missing every account of the task actually being performed. I will reconstruct these tasks, and trace the system of logistical relationships that make them possible. This method of contextual and experiential analysis has gained traction in recent scholarship, and the appearance of Imperial Rome's most famous structures has been subjected to appropriate scrutiny.[4] A growing number of scholars, such as Adam, DeLaine, Favro, Lancaster, and Taylor, have investigated construction methodologies and experiential relationships within the city, and in turn have provided a fundamental paradigm shift for presenting building-specific procedural analyses.[5]

In every city, structures undergo continuous alteration reflecting construction or re-construction, as well as a direct interaction with the evolving urban fabric. Any innovative methodology in the field must bridge the relationship between isolated building technique and the topographical and socio-cultural environment. This study precisely interrogates the symbiotic

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[3] The only direct example of Roman architectural commentary is provided by Vitruvius *De Arch*, which will be addressed at length below. The ancient text is presented with commentary in Rowland and Howe eds. *Vitruvius: 'Ten Books on Architecture*,' Cambridge: Cambridge University Press, 2001. In the text, the Basilica at Fanum is the only work Vitruvius assigned to himself that has any validity in the archaeological record, but there is no specific reference to any construction processes at this monument or any other.

[4] Wilson-Jones *Principles of Roman Architecture*, New Haven: Yale University Press, 2000 (specifically Section X The Enigma of the Pantheon: The Exterior pp199-212) and Waddell *Creating the Pantheon: Design, Materials Construction*, "L'Erma" di Bretschneider, 2008, have suggested that the design and construction processes dictated the final appearance of the porch and impost block of the Pantheon.

[5] Adam *Roman Building: Materials and Techniques*, London: Routledge, 1999; DeLaine *The Baths of Caracalla: A Study in the Design, Construction, and Economics of Large-Scale Building Projects in Imperial Rome*, Portsmouth: Journal of Roman Archaeology, 1997; Favro "Construction Traffic in Imperial Rome: Building the Arch of Septimius Severus," in Laurence and Newsome eds. *Rome, Ostia, Pompeii: Movement and Space*, Oxford: Oxford University Press, 2011: 332-360; Lancaster "Building Trajan's Column," *American Journal of Archaeology* 103 (1999): 419-439; Lancaster "Building Trajan's Markets 2: The Construction Process," *American Journal of Archaeology* 104 (2000): 755–85, and Taylor *Roman Builders: A Study in Architectural Process*, Cambridge: Cambridge University Press, 2003.

relationship between process, product, and environment, and provides an immersive analysis of the construction of the Basilica of Maxentius in central Imperial Rome (see Figure 1). I will consider comprehensive logistics, materials procurement and transport, assembly and organization of construction implements, on-site building process, situational complications, and contextual urban impact. The primary focus is an evaluation of how construction happens in a real environment, and the subsequent challenges in adaptation and ingenuity.

In Rome, the ability to transport massive stone monoliths down narrow streets or mobilize an entire brick-making industry within a matter of weeks are paramount to the success of public building projects. Worksites in Imperial Rome are of particular interest as examples of large-scale construction in a dense urban fabric. In the capital city, every aspect of the construction process is magnified. If a 15-meter marble monolith cannot negotiate a tight corner in the city center, then adjustments or cancellations must be made. If there is not sufficient area for the guide wires of a treadmill crane to be tethered, then important building materials cannot be raised into place. Material shipments are frequently lost in the Mediterranean or damaged *en route*. Each urban

Figure 1: Current state of the Basilica of Maxentius. The northernmost aisle, or one-third, of the structure remains. This view displays only a small portion of the brick-faced concrete masonry carried out in the structure. Photo by author.

project required a coordinated and sequential shutdown of large segments of the central city for material transport. The construction process itself must be incredibly malleable, in order to dynamically shift and mold itself to its host environment.

The process of construction comprises myriad variables, possibilities, and contingencies; its total scope is unequivocally difficult to define. Prior scholarship has tended to ignore such a vast quagmire of uncertainty, and instead has proposed succinct and manageable technical manuals for sequencing the tasks of construction. The frequency of setbacks and likelihood of adjustments are dismissed or undocumented.[6] This study embraces the discord, the uncertainty, and the perceived ugliness and inconvenience of construction. It is not logical to base sole understanding of a building on the end-product, and it would be irresponsible to assume that the construction process did not directly affect its "final" state. Instead of interrogating a monument as a pristine finished product, I will reverse-engineer the Basilica of Maxentius to hypothetically analyze the construction process.[7] Every built project has gone through a construction stage, with some protracted over centuries, and others lasting comparatively longer than the buildings' functional stage.[8] The goal of this study is not to devalue the functional life of a building, but

[6] Indeed, the documentation of communication methods specific to construction processes in Imperial Rome is woefully incomplete. Specific commands or instructions that had been sent and received in all directions along its various infrastructural network arteries have been lost, and the communication methods between central worksite to furthest material supply node must be for the most part reconstructed or hypothesized. See Chapter 4 for a pointed discussion of the informational and communication models extant in the construction process.

[7] A valuable resource here is Amici "The Basilica of Maxentius in Rome: Innovative Solutions in the Organisation of Construction Process," in Dunkeld et al. eds. *Proceedings of the Second International Congress of Construction History*, Cambridge: Cambridge University Press, 2006: pp167-178. Amici analyzes the composition of the brickwork of the Basilica to suggest an overall phasing of construction, including the vaults and aisles. In this work, Amici brings into focus the organization of structural engineering, but does not concentrate particularly on the larger infrastructural processes of construction, which remains a focus in this dissertation.

[8] A Roman example of incredible construction excess is the Domus Aurea, probably never completed by Nero between 54-68 CE, and demolished or altered almost immediately thereafter by the Flavians. Another Greco-Roman example is the Temple of Apollo in Didyma, which featured a Hellenistic-era incarnation never finished through the 4th century CE. Interesting famous examples of large-scale architecture left unfinished in the modern Mediterranean include the *Basilica i Temple Expiatori de la Sagrada Familia* in Barcelona, Spain (under construction continuously from 1882 CE to present), and the *Cathédrale Saint-Pierre de Beauvais* in Beauvais, France (begun in 1225 CE, but never completed).

instead simply to privilege its creation and relationship to the surrounding urban context. In order to successfully position the creational aspects of architectural building, I will set up a relational framework to interrogate the dynamism and malleability of the construction process.

1.2. The Basilica of Maxentius as a contextual case study in the construction process

To this point, the construction process has been dutifully placed in a greater meta-discussion concerning the life cycle inherent to all building. But in order to situate the idea of the construction process in a more manageable context, and to avoid the tendency towards generality, a more focused view must be applied to a specific case study. Rapid advancement in architectural design, engineering, technology, and infrastructure continually changes the appearance and organization of construction sites, and this is unequivocally true in the Roman Imperial period.[9] To posit an efficient solution for understanding the construction process, I will break down the component needs for a singular project and propose a model of the resultant system. The extant compendia of historical construction methods provide a solid foundation for material classification and building technique, and the recent contributions by DeLaine, Lancaster, and Favro provide an increasingly experiential characterization of the entire process as it happens.[10] The principal goal of my research is to apply these techniques and categories to a single project, and identify the procedural and logistical intricacies. The following case study is a direct critique of the totality of building manufacture, a geo-temporal investigation of the size and character of the building site, and a working theory for the overall requirements of large-scale Roman building.

[9] The obvious reference here is to widespread introduction of brick-faced concrete construction in the post-Neronian Imperial era, which changes the materials needed for construction, and in following, the labor and organizational structure of the site and its support arteries.

[10] DeLaine 1997, Lancaster 1999, Favro in Laurence and Newsome 2011.

Although most pre-modern construction has been appropriately labelled as slow, unorganized, and driven by slave labor, Imperial Rome defies all of these generalizations.[11] The Romans were professionally organized and exceedingly efficient. They built quickly, and several simultaneous construction projects seldom posed a problem. Rome's construction industry mastered the manufacture, allocation, and assembly of timber, brick, stone, marble, and concrete. Like many ancient metropolises, Rome was constantly under construction. We can assume that most Romans accepted continual construction and restoration as a part of daily life in the capital, and were limited in their criticism of any inconvenience caused by imperial building projects.[12]

Figure 2: "Scene of a Building Site," painting from caldarium in the Villa of San Marco at Stabiae, Archaeological Museum of Castellmare, no.282. Drawing by author.

Wall paintings that chronicle life on the Roman building site are evidence that construction was considered logical for progress, and even dutifully celebrated by the *fabri* professions (see Figure 2). Perhaps the vast amount of evidence that chronicled building construction was lost after

[11] For the most convincing dispute of slave labor being employed in Rome, see DeLaine "Building the Eternal City: the construction industry of imperial Rome" in Coulston and Dodge eds. *Ancient Rome: The Archaeology of the Eternal City*, Oxford: Oxford University School of Archaeology, 2000, pp119-123. For prior attitudes on ancient construction and engineering apart from the Roman perspective, see Fitchen *Building Construction Before Mechanization*, Cambridge: MIT Press, 1986, preface pp xii-xvii; Landels *Engineering in the Ancient World*, Berkeley: University of California Press, 1978. On Roman construction, see Cozzo *Ingegneria romana: Maestranze romane, strutture preromane, strutture romane, le construzione dell'anfiteatro Flavio, del Pantheon, dell'emissario del Fucino*, Rome: Libreria editrice Mantegazza di P. Cremonese, 1928; Rivoira *Architettura romana: costruzione e statica nell' età imperiale*, U. Hoepli, 1921.

[12] Indeed, most Roman non-elites had little recourse in "complaining" about construction, considering most building projects in the city were carried out by the emperors or wealthy patricians. Most remarks about the state of construction were usually posited as asides in letters of the wealthy (usually complaints about the state of their own homes or the homes of others), including Pliny *Epist*. 2.17, 4.1, 6.10, 51, 55, 56, and Seneca *Ep*. 64-66.

completion of the project, either misplaced, destroyed in re-use, or lapsed in the oral traditions of master and apprentice.[13] Rome has no shortage of extant Imperial buildings in its archaeological record, but this study is centered on one distinguishing project that best distills the dynamic and multi-faceted nature of the Roman construction process.

In order to investigate the variability of all of the factors of the construction process at their most crucial apogee, it is beneficial to identify a case study that is potentially fraught with complications that test the limits of the process. A suitable example must be archaeologically complete, well-attested in the literary record, and securely dated and located within the confines of the Imperial city.[14] For the purposes of this study, smaller buildings in the city center have been discounted, as they required a comparatively non-problematic amount and size of building materials. Although the topographical density of the city center was likely comparable throughout Roman history, constructions dating to the Republican era are severely compromised by continuous Imperial rebuilding and restoration.[15] There have been a few recent surveys of the

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[13] These *fabri* relationships were often chronicled on tombstones, including the Tomb of the Haterii on the Via Labicana and The Tomb of the Baker at the Porta Maggiore. The ancient and medieval melting of metal tools and the disintegration of wooden implements are among the reasons that construction methods were forgotten or misunderstood. Also, inscribed building plans (akin to the modern idea of a blueprint) were likely covered over or erased, see Haselberger "The construction plans for the Temple of Apollo at Didyma," *Scientific American* 253 no.6 (1985): 126-132, and Haselberger "Architectural Likenesses: Models and plans of architecture in classical antiquity," *Journal of Roman Archaeology* 10 (1997): 77-94. Roman building documentation was likely kept and consulted for issues of taxation and ownership disputes, but lack of preservation points to the fallibility of physical documentation or the lack in perceived value of the recorded information. It has only become standardized in recent centuries to preserve building "blueprints" for posterity as well as practical reasons. Nearly all evidence of Roman documentation has been lost, but Diocletian's Edict on Maximum Prices of 301 CE provides details on certain construction aspects, including wages, materials, transportation, and other costs.

[14] Buildings erected *outside* of the city center avoided most of the complications in access to either labor or materials, since most of the production centers and ports would have been convenient to their location. The Roman entry port at Ostia and Portus were located several kilometers from the center of Rome, and relied on the Tiber for easy transference toward Rome's outskirts. Material production centers for brick, timber, pozzolana, and tufa were also outside the city, mostly in the direction of the Alban Hills along the Via Appia, but also along the Via Salaria and Via Nomentana. A construction project in the city center would thus be the most difficult to reach with materials, and the most important to analyze.

[15] An intriguing comparison of each era's architectural density could be made between the Digital Augustan Rome Project (http://digitalaugustanrome.org/), authored by Haselberger et al. *Mapping Augustan Rome*, Ann Arbor: Journal of Roman Archaeology, 2002, and the famed *Plastico di Roma* model of Constantinian Rome executed by

construction of Imperial Roman building projects, but the main comparanda of the Pantheon and the Baths of Caracalla lie outside of the city center, as defined by the Forum Romanum and its immediate confines.[16] Instead, there are more viable exhibitions of the construction process that strictly interrogate all of the necessary variables like topographical density, population density, building size, ease of access to the building site, and socio-historical poignancy in the central city.

The ideal candidate for a case study of the Late Imperial Roman construction process should be relatively intact physically, in or near the center of the city, large in stature, diverse in materiality, and somewhat difficult to furnish with materials, implements, and labor. The early 4th-century Basilica of Maxentius fits all of these criteria. The Late Imperial city of Rome was a dense layered collection of architecture, and the central city was a stratified array of fora, basilicas, temples, altars, and honorific columns.[17] Most of the topography immediately surrounding the Forum Romanum was a dense residential and commercial zone characterized by the Palatine, Capitoline, Aventine, Quirinal, and Oppian Hills, and each interim valley. In order to construct any project near the Forum, Roman builders were forced to consider several variables and develop contingencies for blocked transportation avenues or material shortages.

Italo Gismondi between 1935 and 1971. Also, the recent "Building Augustan Rome" project conducted under Diane Favro at UCLA's Experiential Technologies Center is interested in new ways of comparing separate eras of building construction in one platform using procedural modelling.

[16] Referring specifically to the treatments of the Pantheon by Waddell 2008 and of the Baths of Caracalla in DeLaine 1997; these projects were located in the Campus Martius and outside the Porta Capena, respectively. The city center can be defined roughly for this study as the regions of VIII (Forum Romanum), X (Palatium), and XI (Circus Maximus). The impact of the fringes of other regions on the city center will also be addressed in this study, but this layout is suggested for site justification.

[17] The "Late Imperial" period or "Late Empire" has been used somewhat ambiguously in past scholarship, including being defined recently as 250-450 CE at the "Oxford Centre for Late Antiquity" (http://www.ocla.ox.ac.uk/sect_lre.shtml), or in the 1920s as the entire period from Theodosius I to Justinian in Bury *History of the Later Roman Empire*, New York: Dover, 2012 (original 1923). For the purposes of this study, the period from Diocletian until the replacement of Rome as capital of the Western Roman Empire by Ravenna in 402 CE will be used as the "Late Empire."

Additionally, any construction activity during the era of Maxentius permits an analysis of the dynamic fluidity of the materials industry in the Late Empire.

Rome had been largely ignored by the previous emperor Diocletian, and Maxentius sought to situate himself as the next great builder of Rome.[18] He embarked on a massive program that required expertise and organization, as well as a revival of all of the imperial supply chains and their subsidiary systemic links. The Basilica of Maxentius was a public exhibition of large-scale brick-faced concrete construction, which meant several different streams of materials along distinct lines of network infrastructure.[19] With its soaring vaults, towering monoliths, and intimidating amount of building materials, the basilica provides a remarkable example of Late Roman building technique and experimentation.[20] The design specified eight monolithic columns, which would need to negotiate the aged cobblestones and winding streets of Rome and employ multiple lifting mechanisms to take their place in the relatively cramped interior of the central hall. This very scenario makes the basilica intriguing from both a structural and infrastructural standpoint. These facets provide one of the most impactful constructions of the Imperial period, and thus a perfect example to examine the fluidity of the construction process.

[18] Diocletian reigned from 284-305 CE, but is rumored to have visited the city only once, for his Decennalia in 303. His notable architectural projects include a large bath structure well outside of the city center, the small Decennalia monument in the north Forum, and a rebuilding of the Curia Julia; Rees *Diocletian and the Tetrarchy*, Edinburgh: Edinburgh University Press, 2004, pp29-30.

[19] The most recent and comprehensive principal sourcebook for the Basilica of Maxentius is Giavarini et al. *The Basilica of Maxentius: The Monument, its Materials, Construction, and Stability*, Rome: "L'Erma" di Bretschneider, 2005, which includes contributions by Amici.

[20] The Basilica of Maxentius still exerts a major visual impact on the city of Rome, even considering that only one set of vaults remains on site. The hulking remains of the northern walls make up a large part of the border between Mussolini's Via dei Fori Imperiali and the archaeological remains of the Forum, and today include several maps of Roman Mediterranean domination throughout the epochs. Because of the touristic orientation of the modern Forum and ancient Rome, the Basilica plays a large part in the circulation patterns of the city center. Visitors must either view the Basilica on their way through the Forum, or confront the outside walls on the way from Piazza Venezia to the Colosseum. Also making a major impact on the modern viewer are the permanent metal struts and scaffolding erected to stabilize the structure itself. The floor of the Basilica is frequently open for tourists, and used for concert performances (as of the mid-2000s), and spectators must consider the structural stability of the vaults when in attendance.

1.3. Symbiosis defined: a cautious application of biological metaphor to architecture

In order to explicitly investigate the success of the Late Imperial construction process, I will introduce a new theory to delineate its functionality and integration within the city of Rome. The construction process is necessitated by the impetus of the building itself, then engrains and nests itself within the urban environment where the creation will take place, and spreads its supply-chain arteries in a pattern where it may expand and contract freely along established infrastructural networks furnished by the city. Thus, a symbiosis between the construction process and the city of Rome would imply a working cooperative relationship and a mutually beneficial end-product. In identifying the degree to which a metaphorical association can be drawn between the two, I will establish a definition of symbiosis and formulate a syntax for symbiotic relationships. Scientifically speaking, symbiosis fits within a distinct context as a descriptive term, namely in the establishment of an intimate connection between two phylogenetically distinct organisms.[21] Admitting the term "symbiosis" in this context would thus imply a strictly metaphorical connection between a city and a construction process, in that neither can be systematically defined as a distinct organism. However, if the definition of an organism can be more broadly applied as a living entity with moving parts, infrastructural systems, and a general directive to survive until its purpose has been fulfilled, then symbiosis should indeed be proposed as a model to investigate the construction process.

Symbiosis as a descriptor can be better understood by interrogating its pedigree as a scientific term, which was born of socio-political origins. When marine biologist Pierre Joseph

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[21] Van Driem "Symbiosism, Symbiomism and the Leiden Definition of the Meme," Semioticon 2007, (http://www.semioticon.com/virtuals/imitation/van_driem_paper.pdf) p3; also van Driem "The origin of language: Symbiosism and Symbiomism," in Bengtson ed. I*n Hot Pursuit of Language in Prehistory,* Amsterdam: John Benjamins, 2008, pp381-400. Also see Ahmadjian and Paracer *Symbiosis: An Introduction to Biological Associations*, Hanover: University Press of New England, 1986, pp1-2.

van Beneden was searching for a term to describe mutually beneficial relationships between species, he adopted the French communist moniker “mutuellisme,” and went on to carefully distinguish between several types of symbiotic relationships, including parasitism, commensalism, and mutualism.[22] Mutualism itself is possibly the most accurate subset to assign to the nesting of the construction process within the city fabric, as it is characterized by an “intimate and reciprocally beneficial interdependency.”[23] If intimacy can be taken to mean “closeness,” then the argument is strengthened by the construction process’ physical appropriation of the city’s transportation arteries and mining of the city’s resources. Reciprocity and interdependence will also be explicated during the course of this study, while the beneficence of the relationship may be sufficiently relegated to an ensuing, but co-dependent, socio-cultural analysis. In addition, as “mutualism” fits somewhat ineffectually into the large battery of terms meant to designate the different types of symbiotic relationships, with different scientific connotations, this dissertation will continue to employ the blanket term “symbiosis” to describe the relationship between the construction process and the city. As indicated by the successful generational transformations of the term “symbiosis,” the purposeful employment of such a term here is based on the distinctions made in various recent analyses that suggest broader applications.[24]

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[22] Van Driem 2007, p4, Ahmadjian and Paracer 1986, p3; also consult Van Beneden *Les commensaux et les parasites dans le regne animal*, Paris: Bailliere, 1875 and De Bary *Morphologie und Physiologie der Pilze, Flechten und Myxomyceten*, Leipzig: Verlag Von Wilhelm Engelmann, 1866.

[23] Van Driem 2007, p4.

[24] Sundaralingam “Science and Poetry: Predation or Symbiosis?” World Literature Today, January 2011 (http://www.worldliteraturetoday.org/2011/january/science-and-poetry-predation-or-symbiosis-pireeni-sundaralingam#.VU0qwPlVikq) p4; in particular, Sundaralingam suggests that symbiosis might be employed to investigate the relationship between science and poetry. It should be noted however, that Van Driem 2007, p5 and other sources consider the application of symbiosis outside of the realm of hard science to take on a certain “feel-good, New Age” flavor in popular lay usage (although Van Driem uses symbiosism as a model for the cultivation of language in the human brain).

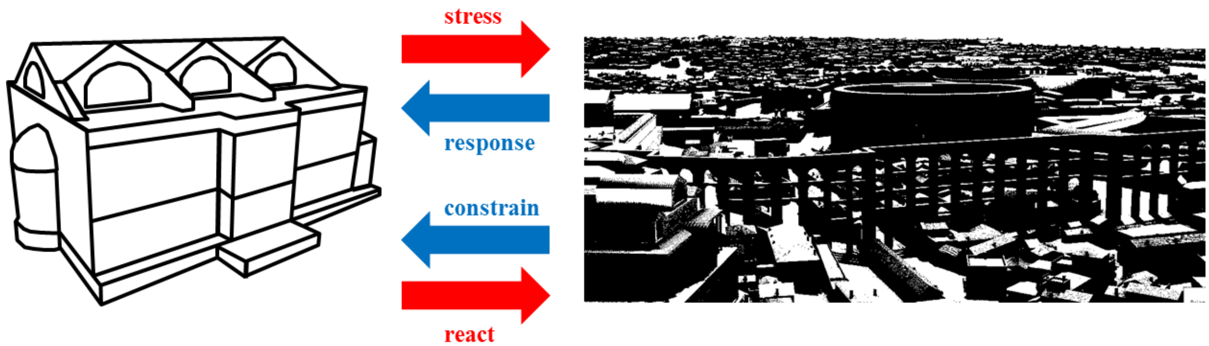

Figure 3: Symbiotic relationship diagram, depicting building and city. Model at right courtesy of UCLA ETC City of Rome.

In generating a paradigm in which the symbiotic relationship of the construction process and the city can be analyzed, I will first delineate the difference between a basic relationship and a symbiotic relationship. A basic relationship implies only that two or more entities are involved, but may have little or nothing to do with each other excepting for a precise point of creation or destruction. A symbiotic relationship conversely implies that the two entities must, in the least, exert or receive a certain amount of force from the opposing entity, and appropriately respond to this force. Existing academic research on construction processes, in addition to commonsense observation of modern construction projects, indicates that any manner of architectural building places great stress on already-congested areas.[25] The symbiotic quotient of this multi-directional equation is at the heart of an analysis of the construction process (see Figure 3). Identifiable vectors of direction and magnitude will indicate the variety of stressors that the construction process and the city exert on each other, and the degree of reciprocal interdependency these two entities can exhibit in the face of such pressure.

[25] Indicated in project management histories Chiu *An Introduction to the History of Project Management: From the Earliest Times to A.D. 1900*, Eburon Delft, 2010, and Kozak-Holland *The History of Project Management*, St. Louis: Multi-Media Publications, 2011; also emphasized in DeLaine 2000, Fitchen 1986, and in the modern study of the construction process Gould *Managing the Construction Process: Estimating, Scheduling, and Project Control*, Boston: Prentice Hall, 2012.

In following, an important investigational metaphor is the conceptualization of the construction process as a multi-dimensional, systemic generator for architectural building. And, as architecture itself and the cities that host architecture have been metaphorically viewed as living entities, it stands to reason that the object that generates both should also be held metaphorically as a living entity.[26] If this appraisal is to be maintained, it follows that the terminology to describe such entities and events must match the corporeal intonation set up by this symbiotic representation. It is useful that architectural construction and biological science share a lexicon for building, as it is appropriate for molecular biology to introduce the "construction" of a cell line to repair mitochondrial DNA, or for pharmaceutical drug design to assign the term "scaffolding" to a fixed part of a molecule on which functional groups are substituted or exchanged.[27]

Thus, identifiers such as transportation "arteries," infrastructural "systems," contextual "fits," labor "energy," and even construction "process" itself might be categorically likened to sentient and organic coordination. In this metaphor, the construction process initially imposes itself upon the city, grows in scope and complexity, and forces a mutual and reciprocal relationship with the city, in order to further its goal of creation. The city becomes a reactive

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[26] For this study, the concept of addressing a city as a living entity is notably advanced by the Roman-specific work Butterworth and Laurence *Pompeii: The Living City*, New York: St. Martin's Press, 2013. As in the Butterworth/Laurence volume, precedent exists in the study of ancient Rome as a living entity; see Favro 1996, also, in Krautheimer *Rome: Profile of a City, 312-1308*, Princeton: Princeton University Press, 1980, the author begins his preface "I have tried in this book to sketch a profile of Rome as a living organism." Also cf. Gruber *Biomimetics in Architecture: Architecture of Life and Buildings*, Vienna: Springer, 2011, Jacobs *The Death and Life of Great American Cities*, New York: Vintage Books, 1961, and even in the work of the biologist/city planner Patrick Geddes, most notably Geddes *Cities in Evolution: An Introduction to the Town Planning Movement and to the Study of Civics*, London: Williams & Northgate, 1915.

[27] For molecular biology definitions, see Lodish, Berk, Zipursky, et al. *Molecular Cell Biology*. 4th ed. New York: W. H. Freeman, 2000, most notably Section 1.3 "The Architecture of Cells." Also, Alberts, Johnson, Lewis, et al. *Molecular Biology of the Cell*. 4th ed. New York: Garland Science, 2002, most notably the section entitled "Most Membrane-enclosed Organelles Cannot Be Constructed From Scratch." For pharmaceutical drug design, see Chitty *Medicinal & Pharmaceutical Chemistry Glossary & Taxonomy: Evolving Terminology for Emerging Technologies*, (http://www.genomicglossaries.com/content/chemistry.asp#molec scaffold), specifically definitions for "molecular scaffold" and "scaffold hopping."

entity, and forges its own set of rules that respond to the construction process. The ultimate result of this symbiotic relationship is the completion of architecture. The construction process then retracts and terminates its relationship, while the completed building maintains a new relationship with the city. The remaindered vestiges of the construction process will take time to dissipate, but may even remain to be seen within the city, and indeed in the architecture itself. The milieu created by the various intersections and interactions of the three entities is a precise goal of this study.

When applying a biological metaphor to the life cycle of a building, the sequential elements of birth, life, and death must be uniformly justified. The "life" of a building has been tied to design and appearance, but the "birth" is a direct function of the corresponding construction process. The process takes advantage of multi-directional networks that were established long before the designs of the building were ever submitted, and relies on infrastructure that reaches across continents and backward through the centuries. The blurring of bracketing endpoints makes it increasingly clear that the building and its construction processes are living entities with obscure origins and specific growth trajectories. The constant in this pseudo-scientific equation is the construction process, which materializes into being while mimicking the city's extant infrastructural arteries and articulating its physical space. The specific function of the construction process is to birth a building. The building cannot exist without the process, which in turn cannot exist outside of the context that the city provides.

The construction process also dictates the conditions of the life and death of the building, even mandating how it is disassembled. As an example, the Basilica of Maxentius eventually lost its columns between the later sacks of Rome and the Renaissance era, but excepting for the possibility of earthquake damage, they were probably removed in the same manner in which they were brought in.[28] The monoliths were only able to be taken down intact by following the same guidelines, using scaffolding or lifting machines, and carted through the same Roman streets to their next re-purposing. The preliminary construction process essentially had established the only pathways and methods suitable for appending and extracting building materials, as well as the crucial maintenance channels utilized during the functional life of the building.

The construction process itself is a multi-directional elastic system, which functions very much like a living entity. It is brought into being precipitously, it must adapt to its surroundings, both in an immediate micro-environment, and in the context of an overarching macro-environment, complete with competing entities that may hinder or support its growth. The construction process has an internal system of growth (the rise of the monument itself), and an external system of growth (with materials coming in, an organic and changing method of building, and byproducts out). Each support system has a set of moving parts, and the conditions can change very quickly. The Basilica of Maxentius was only created as fast and as efficiently as the conditions of the construction process would allow. If the columns did not fit into their apposite piers, or the staging area for bricks was insufficient, adjustments were made while the efficiency suffered. The architecture itself serves as the ultimate product, but even the mass of the basilica still pales in comparison to the vast volume of energy totaled during the process of construction.[29] In order for the "energy" of the construction process to be created, however, there

[28] For instance, a 9th-century earthquake destroyed parts of the Basilica of Maxentius, and by the 17th century, only one of the original eight columns was believed to remain standing. This last column was then removed and brought to the piazza in front of Santa Maria Maggiore in 1614 by Pope Paul V and re-appropriated as a Marian Column by Carlo Maderno. Since the central piers, the lateral vaults, and the end walls were probably still intact at this time, the column must have been removed with respect to its surroundings. The original process of erecting the columns was likely reverse-engineered to remove them.

[29] Energy here is an allusion to the mechanical usage in physics, and to the study of architectural energetics. The "energy" of physics calculations is thus used in combination with "work" and "power" as calculable variables, and each is integral to the study of the construction process. For use in manpower, consult DeLaine 1997, pp104-107, 268-269. Precursors to this type of use of energy in economic and anthropological study have been summed up nicely in Buenstorf *The Economics of Energy and the Production Process,* Cheltenham: Edward Elgar, 2004, pp10-

is necessarily a reaction between base elements, in this case between the basilica and the city of Rome.

1.4. The establishment of building and city as foundational elements for a working process

In order to posit the creation of the basilica as the functional result of a forged symbiotic relationship, I will overlay the intermingled framework of the construction process and infrastructural networking onto the complicated character of Rome, and outline the qualities of

Figure 4: Author rendering of a column being dragged through Rome observed by spectators, using “Mussolini’s monolith” as an analog. Image of Digital City of Rome used courtesy of UCLA ETC.

20, specifically the subsection “Energetic Approaches to Economic and Cultural Development.” Architectural energetics as a concept owes specifically to the prehistorical, North American, and Egyptian archaeological work of Bruce Trigger, including most notably in the article Trigger “Monumental Architecture: A Thermodynamic Explanation of Symbolic Behaviour,” *World Archaeology* 22 no.2 (1990): 119-132. Another application to ancient architecture is provided by Abrams *How the Maya Built Their World: Energetics and Ancient Architecture*, Austin: University of Texas Press, 1994. An inter-disciplinary study informing the physical potentialities of Roman architecture are Homer-Dixon *The Upside of Down: Catastrophe, Creativity, and the Renewal of Civilization*, Washington DC: Island Press, 2006; pp31-56, and an additional section on Baalbek. An early Roman Imperial study on energy requirements within the Julio-Claudian age, and its requisite calculation in specific tasks, is provided in Section II: Manpower Costs of the Building Programs in Thornton and Thornton *Julio-Claudian Building Programs: A Quantitative Study in Political Management*, Mundelein, IL: Bolchazy-Carducci Publishers, 1989; pp15-30.

the urban environment that allow it to successfully host a complementary organism. In this paradigm, the complete topographical make-up of the city is much more important than the few plots of land in and around the building's footprint. The city holds the ports, the warehouses, the material staging areas, the workers' housing, the implement storage, and the transportation avenues. The organic irregular road system creates the possibilities for supply bottlenecks and large material repositioning, and the contoured geography of the seven hills provides a format for spectators to watch the activity (see Figure 4). The city can be a chaotic, pulsating mess, but it needs to simultaneously host a precise, choreographed exhibition of technical merit. It may in fact host several at once.[30]

Rome collectively presents a large spate of critical issues, owing to centuries of organic growth and the near-constant state of reinvention. The central city was a hub of activity, and the Forum Romanum a difficult place to build. Aside from a duplicate rebuild of the Curia Julia by Diocletian, there had been no large-scale construction in the Forum since Septimius Severus one hundred years prior to the Maxentian era, in part because the density near this chaotic junction had made building difficult.[31] The southern Forum was so claustrophobic that the Basilica of Maxentius was designed to incorporate a covered street into its northwest foundations.[32] This is just one example of the complicated context that builders dealt with in the heart of Rome.

[30] As mentioned earlier, Augustus boasted to have constructed or refurbished almost 100 buildings during even the first few years of his reign. This meant several active construction sites at once, in close proximity to each other, as indicated by his interest in the Campus Martius, Forum Romanum, and Palatine Hill areas. Several other emperors built many projects concurrently, including the Flavians, Hadrian, Trajan, and the Severans. As elucidated here, Maxentius was one of the emperors who sought to build several projects at once within Rome (and in Maxentius' case, outside the walls of Rome as well, at his Appian Way Villa).

[31] The only other Diocletianic building project in the Forum was the small Decennalia Monument set up next to the Arch of Septimius Severus, but this was in essence akin to the simple erection of honorary columns with their bases in a relatively open space of the forum. The largest project was the Baths of Diocletian, built near the Quirinal and Viminal hills at the edge of the city. This project, likely supplied with materials through the Porta Nomentana, is now held to be largely the idea of Maxentius as well. The forum area was presumably as dense as it was in the earlier Empire, but the aforementioned several new hubs of activity had shifted the idea of the city center of Rome.

[32] The Via ad Carinas, which will be discussed in conjunction with its re-direction during the construction process.

Although most historical monuments were forced to confront convoluted topographical strata in any setting, each late Imperial Roman project was subject to a comprehensive collection of pre-existing urban armatures and infrastructural systems characteristic of nearly 1000 years of building.[33] In order to erect the Basilica of Maxentius, the builders had to confront the surrounding urban fabric, and forge an intensely synergetic relationship with the collection of interrelated construction components and pre-existing buildings.

In Imperial Rome, socio-cultural manipulation and political power played a large part in the construction and refurbishment of buildings.[34] Maxentius' usurpation in the early 300s C.E. provided an opportunistic impetus for construction in the city center, and a massive basilica at the southeastern entrance to the Roman Forum was built as the architectural showpiece for this newfound power.[35] The new "emperor" of Rome had his eye fixed on a particular spur of the Velian Hill that was connected to his family name, and he began augmenting the personal glory

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[33] The simultaneous existence of layered topography and previous building typologies in Rome are also a factor in the building's design and the construction process. The enumeration of the building's construction process informs the final appearance of the building, but also "etches" into the building a series of physical documents to inform all buildings of this type to come. These documents function as a "text," which are informed by "buildings as texts" before them, and will hold important information for further buildings. "Building as text" was specifically investigated in the UCLA Grad Colloquium conducted by Dana Cuff in the fall of 2008; also see McLuhan *Understanding Media: The Extensions of Man*, Cambridge: MIT Press, 1964, and Longacre "Hermeneutic Observations on Textlinguistics and Text," in Lockwood, Fries, and Copeland eds. *Functional Approaches to Language, Culture, and Cognition: Papers in Honor of Sydney M. Lamb*, Amsterdam: John Benjamins Publishing, 2000, p179 (section 4.3 Text theory and architecture).

[34] See Gerding "Public Building and Clientage: Social and Political Aspects of Roman Building Industry," Lund University, Working Paper, 2014.

[35] For Maxentius' usurpation see Culhed *Conservator Urbis Suae: Studies in the Politics & Propaganda of the Emperor Maxentius*, Uppsala: Paul Astroms, 1994, and Corcoran *The Empire of the Tetrarchs: Imperial Pronouncements and Government AD 284-324*, Oxford University Press, 2000. The archaeological and historical records generally agree on a construction period of 306-312 CE for the Basilica of Maxentius, but the exact dating is troublesome. Maxentius ruled serendipitously from October 28, 306 to October 28, 312, but this period of time is characterized by uncertainty and violence; thus, it is difficult to assign specific starting and ending dates for construction, much less specific imperial involvement in the building plans. Moreover, when architectural construction dates are given as a specific timeframe covering a period of monarchic or imperial rule, it is given that the building was not begun the day of coronation and completed the day of death or resignation. Maxentius' successor Constantine actually finished the basilica and added a northern apse, which obfuscates a discussion of the basilica's actual function (theorized by Coarelli *LTUR* B. Const. entry 1.6 to be the main judiciary seat of the urban prefecture).

of the Valerian line in one of the last areas of central Rome to be inundated by large-scale monumental architecture. Maxentius promptly ripped out the *Horrea Piperatoria* spice warehouses, razed a smaller shrine to the Penates, and even leveled part of the hill to make way for his new architectural program.[36] Some of the notable surrounding structures remained, including Vespasian's Forum of Peace, the Temple of Venus and Rome, and the eastern reaches of the Palatine residences. The Temple of Venus and Rome had been damaged by the Fire of Carinus in 283, and the restoration of the massive terraced temple that lie just a few feet from the basilica's foundations became a nuanced part of Maxentius' (re)-building program.[37] That the Basilica, the Temple of Venus and Rome, and the small vestibule temple built for Maxentius' son Romulus were linked strengthens the idea of a symbiotic relationship with the living city, in this case as Rome strategically "repaired" and reconstituted itself after the fire. In following, the acreage immediately surrounding the three projects necessarily functioned as an interrelated and multi-phase shared use area for staging materials, storage, and labor organization.

This combinatory construction site likely sprawled from the northern corner of the Forum Romanum all the way to the Colosseum Valley, with offshoots up the shallow east slopes of the Palatine, into the open areas of the Imperial Fora, and even towards the western slope of the Caelian Hill (sees Figure 5). The ability of the city center to handle this type of building load would be pivotal to the idea of a construction process symbiotically nesting in the middle of Rome. The basilica in particular would exert quite a strain on the material networking

[36] This and several details of Maxentius' building program, are covered in Chapter 2 - The Basilica of Maxentius Re-Positions the Issue of the Construction Process. The topic is also based on prior research by the author in the Master's Thesis entitled "The Propaganda of the Emperor Maxentius: An Expansion of Roman Architectural Topography," University of Colorado, 2006.

[37] The Fire of Carinus may have damaged several structures in the Forum area, in addition to the Temple of Venus and Rome. Coarelli *Rome and Environs: An Archaeological Guide*, Berkeley: University of California Press, 2007 (2014), p73 mentions that even the Basilica Iulia on the other end of the Forum was restored "by Diocletian" following the fire, which alludes to the possible scope of damage. Since Diocletian rarely had a presence in Rome, Maxentius likely initiated some of the restoration efforts himself. Maxentius probably used the damage not addressed by Diocletian to spearhead his building program.

component, especially considering the considerable distance from both the supply ports and material production centers.[38] The construction process would thus principally rely on provisions that the city innately supplies, such as the infrastructural framework and transport avenues. Similarly, it was a relieving aspect that centuries of building in the capital had already built a successful labor network. Each constituent element of the basilica's construction process either establishes itself in the vibrant infrastructure of the city of Rome or additively transforms a part of the city's character. In this study, I will describe the construction of the basilica as a manifestation of a symbiotic, mutualistic relationship between the city and the process of Roman construction.

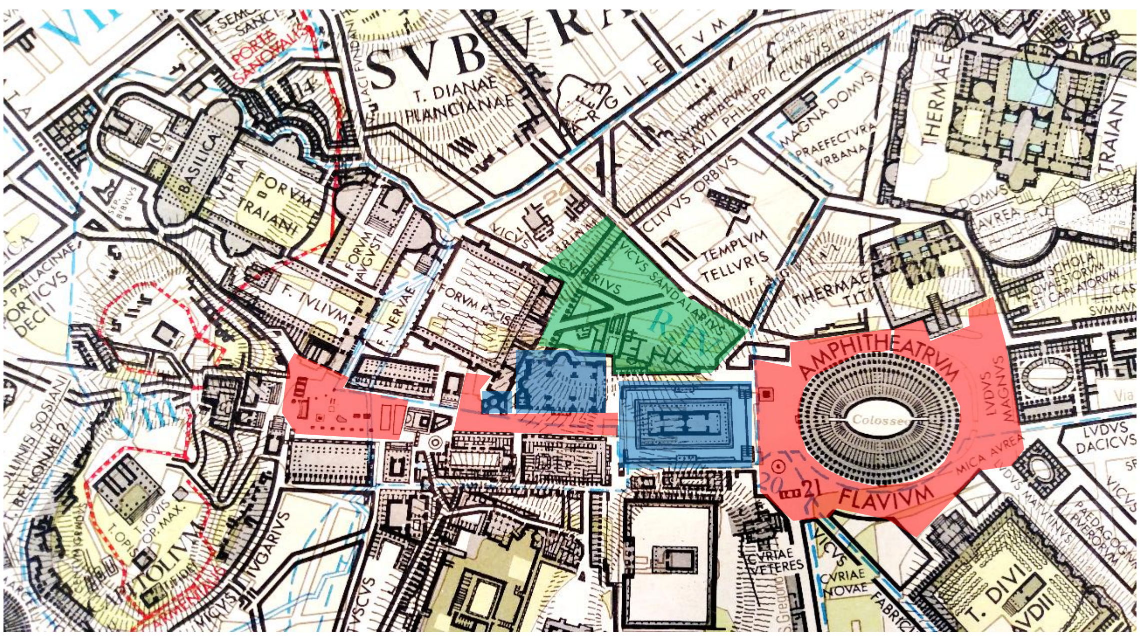

Figure 5: Central quadrant of Imperial Rome, depicting the extent of Maxentian construction area. Blue indicates Maxentian constructions, green indicates extent of modified Velian Hill, red indicates possible material staging areas. Map credit: Scagnetti *Roma Urbs Imperatorum Aetate*, Rome: Staderini S.p.A., 1979.

[38] The Basilica of Maxentius was over 2 kilometers from the major material storage yards at the Emporium, and even further from the city walls, where other materials would have necessarily been funneled through.

1.5. Assessment of methodology and the state of current scholarship

In response to the multifaceted nature of the construction process, I will break down the infrastructural and logistical frameworks that generate architectural monuments, and describe the synergistic relationship between building process and the immediate environment. Foundations for the study of large-scale Imperial Roman building were established in part by two volumes of *The Architecture of the Roman Empire* by William MacDonald, which adapted the material of earlier seminal Italian-language studies by Crema, Rivoira, and Cozzo, and effectively re-oriented the field.[39] The most recent studies in the area of the construction process and technique have been provided by Adam, DeLaine, Favro, Lancaster, and Taylor.[40] These scholars have based their inquiry on descriptions from Vitruvius, archaeological evidence, and various historical accounts of the construction process, ranging from quarry to port to building site.

Jean-Pierre Adam's *Roman Building* of 1999 (initial French-language version published in 1989) is the best recent foundational study of Roman construction techniques and building materials, and it follows in the tradition of Marion Blake's three-volume compilation *Ancient Roman Construction in Italy* that dates to the 1940s-1970s.[41] Adam organizes large amounts of raw data and subsequently presents each aspect of ancient Roman building practice separately in subsections, with only a small nod to the chronological order in which these steps are achieved in practice. The first chapter, on surveying, is presented without a precursory methodology for

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[39] MacDonald 1982, MacDonald 1986, Crema *L'Architettura Romana*, Societa Editrice Internazionale, 1959, Rivoira 1921, Cozzo 1928. Also included in this discussion is the later Italian volume Giuliani *L'edilizia nell'antichita*, Rome: La Nuova Italian Scientifica, 1990.

[40] Adam 1999, DeLaine 1997, DeLaine 2000, Favro in Laurence and Newsome 2011, Lancaster 1999, Lancaster "The process of building the Colosseum: the site, materials and construction techniques," *Journal of Roman Archaeology* 18 (2005): 57-82, Taylor 2003. Also see the recent volume Amici *Architettura romana. Dal cantiere all'architetto: soluzioni concrete per idee progettuali*, Rome: "L'Erma" di Bretschneider, 2016.

[41] Adam 1999, Blake *Ancient Roman construction in Italy from the prehistoric period to Augustus*, Washington DC: Carnegie Institution of Washington, 1947, Blake *Roman construction in Italy from Tiberius through the Flavians*, Washington DC: Carnegie Institution of Washington, 1959, Blake *Roman construction in Italy from Nerva through the Antonines*, Philadelphia: American Philosophical Society, 1973.

investigating the overarching process of construction, and the volume proceeds descriptively rather than prescriptively. Adam does not illuminate one case study, but instead has sought to clarify Roman construction technique as a whole.[42]

Conversely, the more monument-specific work of DeLaine, Lancaster, Favro, and Amici has served to fill the lacunae left by such encyclopedic studies and compendia.[43] In the volume *The Baths of Caracalla: Design, Construction, and Economics,* DeLaine has applied a comprehensive knowledge of building construction to one specific monument in Rome.[44] The Baths of Caracalla were built during the construction boom of the High Empire, and although the expansive complex required an abnormally large amount of building materials, its location near the lesser-populated *horti* of the southern city allowed for a seamless management of the supply chain. DeLaine complements the data collected by Adam, and advances the study of the construction process by employing exhaustive calculations based on the singularities inherent in fabricating solely the baths, as opposed to delineating the entire field of construction technique.

Likewise, Lancaster's important article *Building Trajan's Column* echoes the methodology of closely analyzing the construction of a singular Roman monument.[45] The intricacies of the column itself merit a detailed look at possibilities for innovative construction techniques, especially considering the relative inimitability of a hollow column delivered in

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[42] Adam's work is a foundational study for Roman building practice; for supplements on other ancient building practice see Clarke and Engelbach *Ancient Egyptian Construction and Architecture*, New York: Dover Publications, 1990 (orig. 1930), and Coulton *Ancient Greek Architects at Work: Problems of Structure and Design,* Ithaca: Cornell University Press, 1977. Also, Adam, Clarke/Engelbach, and Coulton have recently been joined by another Spanish-language two-volume set highlighting Roman construction, Camporeale, Dessales, and Pizzo eds. *Arqueología de la construcción I: Los procesos constructivos en el mundo romano: Italia y provincias occidentales*, Merida: Consejo Superior de Investigaciones Cientificas, 2008, and Camporeale, Dessales, and Pizzo eds. *Arqueología de la construcción II: Los procesos constructivos en el mundo romano: Italia y provincias orientales*, Madrid-Merida: Consejo Superior de Investigaciones Cientificas, 2010.

[43] Also, volumes like Giuliani and Verduchi *L'Area Centrale di Foro Romano*, Olschki: Firenze, 1987 serve to bridge the gap between studies of monuments or areas and the logistics and practicalities of construction.

[44] DeLaine 1997.

[45] Lancaster 1999.

carved drum sections. The height, weight, and heft of the column segments produced the need for extraordinary constructions implements, and Lancaster borrows from ancient literary evidence to create such tools. Lancaster employs a pointedly speculative model for building the column, including several vividly-sketched representations of a lifting tower. The recent development of admitting a higher degree of speculative theory into Roman architecture and archaeology is particularly important to this study, especially considering the dearth of explicit evidence of purpose-built construction implements at the Basilica of Maxentius and other comparison projects. I am proposing several hypotheses on the arrangement and logistics of the construction process, which is a tactic employed most recently in Lancaster's 2005 article "The Process of Building the Colosseum" and Favro's 2011 essay "Construction Traffic in Imperial Rome: Building the Arch of Septimius Severus."[46]

In *Roman Builders*, Rabun Taylor has combined the encyclopedic approach of Adam and Blake with the monument-specific approach emphasized by DeLaine, Lancaster, and Favro to posit an overarching theory concerning both the austere daily undertaking and ultimate objective of Roman builders.[47] This volume is one of the most recent attempts to demystify Roman building, and to ground it in remedial construction tasks. Although much of the success of large-scale construction lies in the ability of overseers to cope with unforeseen impediments and make adjustments on site, it also hinges on the obstinate challenge of persisting within the immediate urban environment. As evidenced by his various sketches depicting cranes without a physical tether and structures without any neighboring condition, Taylor has constructed his ancient buildings without regard for the surrounding context. In addressing this exact lacuna, the current

[46] Lancaster 2005, Favro in Laurence and Newsome 2011.

[47] Taylor 2003.

study will establish as primary directive the symbiotic relationship between the native context of the Late Imperial city of Rome and the impending basilica building project.[48]

As mentioned, Carlo Giavarini and his colleagues recently published a pivotal volume on the Basilica of Maxentius and its materials, and the ultimate goal of this CISTeC-produced text was to provide a justification for the stability and conservation of the monument.[49] Giavarini's survey, and specifically the sections contributed by Carla Maria Amici, is invaluable for both its assessment of the amount of physical building blocks that remain at the basilica's archaeological site and the appropriate material provenance listings.[50] Although this seminal text is not concerned with addressing the context of the city as the host for the building project, it will increasingly be relied upon as the principal sourcebook, in combination with select topographical surveys of Rome, era-specific analyses, and other comparanda.[51]

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[48] One of the most complete descriptions of the character of the Late Imperial city has been given in Krautheimer 1980; particularly the introductory portion pp3-18 of Chapter 1: Rome and Constantine. Also see Lancon *Rome in Late Antiquity: Everyday Life and Urban Change, AD 312-609*, New York: Routledge, 2001. The most contemporary rendering of the Late Imperial city has been given in the introductory two chapters in Dey *The Afterlife of the Roman City: Architecture and Ceremony in Late Antiquity and the Early Middle Ages*, Cambridge: Cambridge University Press, 2015; pp33-64. For the most recent comprehensive reviews of the monuments of the city, see Claridge *Rome: Oxford Archaeological Guide*, Oxford: Oxford University Press, 2010, and Coarelli 2007. Other compiled compendia series relating to the make-up of Roman architecture are Ulrich and Quenemoen eds. *A Companion To Roman Architecture*, Malden: Wiley Blackwell, 2014; Erdkamp ed. *The Cambridge Companion To Ancient Rome*, Cambridge: Cambridge University Press, 2013; and Coulston and Dodge 2000.

[49] Giavarini 2005. Also see Care *L'Ornato Architettonico Della Basilica Di Massenzio*, Rome: "L'Erma" di Bretschneider, 2005.

[50] Specific sections concerning the construction process by Amici that will be referenced in this study include Chapter 2: From Project to Monument pp21-74 and Chapter 5: Construction Techniques and Processes pp125-160. Also invaluable is Chapter 4: Materials pp93-124, contributed by Giavarini. These sections are complete with diagrams and tables, and will be significant to many aspects this study. The explicit process of construction is not a specified goal according to the introduction of the text written by Guarini, and the entirety of the infrastructural networks and context of Rome are not discussed in detail.

[51] Topographical surveys include Platner and Ashby *A Topographical Dictionary of Ancient Rome*, Cambridge: Cambridge University Press, 2015 (orig. 1929), Richardson *A New Topographical Dictionary of Ancient Rome,* Baltimore: Johns Hopkins University Press, 1992, the 6-volume set Steinby *Lexicon Topographicum Urbis Romae: Volume 1-6*, Rome: Quasar, 1993-2000, and Carandini ed. *Atlante di Roma Antica*, Rome: Mondadori Electa, 2012; era-specific studies include Harris ed. *The Transformations of "Vrbs Roma" in Late Antiquity: the proceedings of a conference held at the University of Rome "La Sapienza" and at the American Academy of Rome*, Portsmouth: Journal of Roman Archaeology, 1999, Donciu *L'empereur Maxence*, Bari: Edipuglia, 2012, Corcoran 2000, and Culhed 1994.

Primary Roman literary sources seldom cover construction or building of any kind, with the exception being Vitruvius (c.80-15 BCE) *De architectura libri decem*.[52] As the only enduring figure in architectural writing from the Roman world, Vitruvius dictates much of what is known about the design and conception of architectural works. He is more concerned about the ideal form of buildings than the carrying out of construction tasks, although he does describe several useful implements such as treadmill cranes and siege towers. One of the relative drawbacks in using Vitruvius to elucidate the construction process is the date of his work. Since he published *De Architectura* during the reign of Augustus, he only would have been familiar with the design, engineering, organization, and technology of the Late Roman Republic. Vitruvius was writing before the Roman architectural revolution, the widespread use of concrete, and the later installation of ports and warehousing. One benefit to closely reading Vitruvius is the likelihood that certain functional aspects of construction remained constant throughout the Roman Empire, including scaffold building technique, certain material supply networks, and building contractor guilds. Rather than focus on Vitruvius' inherent shortcomings, it is vital to recognize his relevance against the stark absence of any other true primary sources on the construction process.

Apart from *De Architectura*, the most useful literary sources are undoubtedly imperial decrees and other official recordkeeping. Diocletian's "Edict on Maximum Prices" in 301 CE sought to fix prices for goods and services, and modern economists and scholars can utilize its near-complete listing of materials, transport costs, and labor wages.[53] This largely ineffective

[52] For the best English-language translation and commentary of Vitruvius, consult Rowland and Howe 2001. Also see Gros' introduction and work on Vitruvius in Corso and Romano eds. *Vitruvio De Architectura*, Turin: Einaudi, 1997, Fleury et al eds. *Vitruve: De l'architecture, Livre I, texte etabli, trad. et comm. par Fleury*, Paris: Les Belles Lettres, 1990, and Faventinus and Plommer *Vitruvius and Later Roman Building Manuals*, Cambridge: Cambridge University Press, 1973.

[53] For Price Edict, see Corcoran 2000, pp. 440 and Graser "A text and translation of the Edict of Diocletian," in Frank ed. *An Economic Survey of Ancient Rome Volume V: Rome and Italy of the Empire*, Baltimore: Johns Hopkins Press, 1940.

edict served to spike inflation and disrupt trade and commerce in the Roman Empire, but it remains a seminal document in understanding the first decade of the 4th century.[54] Additional records, such as transcripts from legal cases involving property and contract disputes, are another essential source for interpreting the circumstances of construction in the Late Empire. One such case provides a legal reading of an accident involving a runaway cart of supplies careening down the Capitoline Hill and killing a slave boy.[55]

There are a few other unique sources that contribute to the understanding of various aspects of the construction process, including the 1st-century C.E. texts Frontinus (c.40-103 CE) *On Aqueducts* and Pliny the Elder (c.23-79 CE) *Natural History*.[56] Frontinus' text has intrinsic value as one of the only official reports of a Roman engineering work to survive, and Pliny's encyclopedic volume contributes sections on mathematics, geography, mining and mineralogy, and to a certain extent art history. In addition to the preceding purpose-written texts, there are many other Roman literary works ranging from poetry to historical writing that add to this study in the form of offhanded remarks or social commentary.[57] This type of evidence is often the most useful, as unsolicited opinion can often be unbiased. Unorthodox sources often are refreshing, and several such examples from outside the field of ancient architectural history prove valuable.

[54] Lactantius *De mort. pers.*7.6-7.7 is critical of the Price Edict in his Christian-apologetic work during the Late Empire. See Potter *The Roman Empire at Bay, AD 180-395*, London: Routledge, 2004, p328.

[55] The law case taken from Justinian (trans. Kolbert) *The Digest of Roman Law: Theft, Rapine, Damage and Insult*, London: Penguin Books, 1979; case 52 (Alfenus).

[56] Frontinus (trans. Bennett) *The stratagems and the aqueducts of Rome*, Cambridge: Harvard University Press, 1980, Pliny (trans. Rackham) *Natural History: Books 12-16*, Cambridge: Harvard University Press, 1986, Pliny (trans. Eichholz) *Natural History: Books 36-37*, Cambridge: Harvard University Press, 1971.

[57] Among others, this study uses selections from Tibullus (trans. Postgate) *Tibullus: Complete Works*, Delphi Classics, 2015, and Marcellinus (trans. Rolfe) *Ammianus Marcellinus, Volume 1-3*, Cambridge: Harvard University Press, 1950, Coleman *Martial: Liber Spectaculorum*, Oxford: Oxford University Press, 2006, Magie *The Scriptores Historiae Augustae, In Three Volumes*, London: William Heinemann, 1922, and Suetonius (trans. Graves) *The Twelve Caesars*, London: Penguin Books, 2007.

As much as it may be considered a new direction in the scholarship of the ancient construction process, this study remains grounded in the contextual and experiential study of monuments and urban environments. The critical works that serve as the foundation for this type of research are Favro's *The Urban Image of Augustan Rome* and Laurence and Newsome's *Rome, Ostia, Pompeii: Movement and Space*.[58] In addition, a variety of information has been culled from the methods of other archaeologists, historians, anthropologists, classicists, and art historians, and evaluated from an architectural perspective. In precisely this manner, I seek to combine an understanding of the immediate geo-spatial implications of construction with an awareness of the overall socio-cultural milieu that contains each building project. By necessity, this means a close reading of each individual construction aspect. Foundational references here include DeLaine on economics of material and labor, Fant and others on marble procurement and transport, and Lancaster and Taylor on speculative possibilities for construction technologies and techniques.[59]

In order to emphasize multi-faceted *modus operandi*, I will buttress discipline-specific research with specialized approaches developed in neighboring academic domains. This study will contextualize Roman architectural production with seminal work in the fields of energetics,

[58] Favro *The Urban Image of Augustan Rome*, Cambridge: Cambridge University Press, 1996; Laurence and Newsome 2011 (including Favro's contribution). Also relevant are Noreña *Imperial Ideals in the Roman West: Representation, Circulation, Power*, Cambridge: Cambridge University Press, 2011, and Davies *Death and the Emperor: Roman Imperial Funerary Monuments from Augustus to Marcus Aurelius*, Austin: University of Texas Press, 2004.

[59] DeLaine 1997, Fant "Rome's Marble Yards," *Journal of Roman Archaeology* 14 (2001): 167-198, Fant "Ideology, gift, and trade: a distribution model for the Roman imperial marbles," in Harris ed. *The Inscribed Economy: production and distribution in the Roman Empire in the light of instrumentum domesticum: the proceedings of a conference held at the American Academy of Rome on 10-11 January, 1992*, Portsmouth: Journal of Roman Archaeology, 1993, Herz and Moens eds. *Ancient Stones: Quarrying, Trade and Provenance*, Leuven: Leuven University Press, 1992, Herz and Waelkens eds. *Classical Marble: Geochemistry, Technology, Trade*, Leiden: Brill, 1988, Lancaster *Concrete Vaulted Construction in Imperial Rome: Innovations in Context*, Cambridge: Cambridge University Press, 2005, and Taylor 2003.

site-catchment analysis, biological science, spectacle, and networking dynamics.[60] Although several of these methodologies have only been peripherally applied to Imperial Rome, I will also consider themes directly applicable to the construction process, including operational sequencing (*chaîne opératoire*), logistical supply chain administration, and project management.[61]

By integrating several disparate academic approaches that consider more appropriate dualistic narratives for ancient building into era-specific treatises, I will secure a new framework for analyzing the interrelated components of the construction process in Imperial Rome. This methodology introduces a relevant and impactful discourse on the essence of building as a natural function, a biological imperative. Necessarily, this approach grounds the inorganic in an organic paradigm, and applies a situational assessment of the success of biological narratives to explain non-biological entities. The field of architectural history continues to employ a biological vocabulary of life, death, and evolution to describe non-sentient monuments, and I will use this shared lexicon to present a new conception of construction methods and building sites.[62] Previous studies have nested monuments in the context of the city, but rarely have they conceptualized the larger construction process as an entity with its own character and design. If we view the process as a sentient entity, then it follows that the process has its own needs and directives, and these directives are performed by appropriate agents, including designers,

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[60] Trigger's work on energetics is contextually useful to Roman architectural history because the crux of his theory was forged in the complementary fields of ancient archaeology and anthropology. Energetics, networking dynamics, and site-catchment analysis will be applied in Chapter 2 concerning infrastructural networks, and spectacle theory will be enumerated in Chapter 3. This chapter has set up biological metaphor and relies on definitions of Van Driem 2007, Ahmadjian and Paracer 1986, Sundaralingam 2011, Lodish, Berk, Zipursky 2000, and Alberts, Johnson, Lewis 2002.

[61] For *chaîne opératoire* see Sellet "Chaîne Opératoire: The Concept and its Applications," *Lithic Technology* 18, nos.1&2 (Spring/Fall 1993): 106-112, Leroi-Gourhan *Gesture and Speech*, Cambridge: MIT Press, 1993 (orig. 1964), Pelegrin, Karlin, and Bodu "'Chaîne Opératoires': un outil pour le prehistorien," in Tixier ed. *Journee d'Etudes Technologiques en Prehistoire , Notes et Monographies Techniques* 25, Paris: Editions du CNRS, 1988: 55-62, Lemonnier ed. *Technological Choices: Transformation in Material Culture since the Neolithic*, London: Routledge, 1993, Izzet *The Archaeology of Etruscan Society*, Cambridge: Cambridge University Press, 2007, and Smith *How the Great Pyramid Was Built*, New York: Harper Collins, 2006.

[62] See the aforementioned works of Butterworth and Laurence 2013, Gruber 2011, Jacobs 1961, and Geddes 1915.

craftsmen, laborers, streets, trade routes, brick kilns, and cranes. As the construction process adapts to its surrounding infrastructural networks and host environment, it forms tacit connections and directional ties that resemble neural pathways or, in terms of the city, transportation hubs.

A successful re-orientation of the field will thus introduce the idea of a shared syntax and establish a multi-faceted symbiotic relationship borne out in the city of Rome. The second chapter will immediately introduce several paradigms for understanding the infrastructural systems of Imperial Rome, and how they function within the direct context of architectural building. The networks that are employed to create a single project like the Basilica of Maxentius are incredibly complex and far-reaching, and this chapter considers large-scale dynamic constructs as well as micro-pathways, hubs, material payload deliveries, labor supplies, and task repetition. In this chapter, I set up the base components of the Roman construction process and the urban topography of the Late Imperial city, and propose a mutually symbiotic relationship to describe the resultant reaction. In the third chapter, I will analyze the specific junctures during the course of the construction process wherein this relationship is palpable, and indeed visible. I posit that the spectatorship and subsequent recording of construction events by the Romans should be held as the strongest evidence of such a successful symbiosis. The episodes of greatest peril and logistical ingenuity reveal several of the most dynamic relationships in the entire network of building. The fourth chapter presents the logistical sequencing of construction and the variety of scenarios that unfolded during the generative process at the Basilica of Maxentius. This section addresses the daily necessities and adjustments made at the building site, and elucidates the overall impact that large-scale projects had on the surrounding urban environment.

The concluding chapter presents a new model for considering Imperial Roman construction as a relational network of dynamic processes that nest symbiotically within the urban context.

2. Rome's Infrastructural Networks for Construction: Materials, Transport, and Labor

2.1. The multi-faceted infrastructures of the construction process

A mutually beneficial relationship implies two entities that are working together towards some end. A symbiotic relationship insinuates a "host" organism sharing its arteries and annexes with a "guest" organism in order to pursue a similar end. The host must provide all foundations and infrastructure, as the guest has furnished none of its own. Accordingly, a building's construction process can only have a successful fruition if the city in which it nests has set up a multifaceted and dynamic system conducive to all of its needs. After defining the nature of the relationship between guest and host, the next logical progression is to understand exactly how the city sustains the stresses of the process, and how it has been equipped to do so. The early 4th century city of Rome was certainly a complex entanglement of infrastructural pathways and junctions, but each component functioned according to its own stringent guidelines and support structure to meet the requirements of architectural building. A centralized system of municipal offices governed and maintained this infrastructure, which thus provided the physical space of the building site and its storage spillover, as well the arteries that brought materials, labor, implements, and everything else imaginable from their sources to the site.[63] Each of these separate but complementary infrastructural networks followed a complicated sequencing to arrive at their 4th century configuration, and it is important to understand the slippage between their geo-temporal connections and the resulting multifunctional model for construction.

[63] For the administration and development of Roman urban planning and associated works, see Robinson *Ancient Rome: City Planning and Administration*, London: Routledge, 1994 (orig. pub. 1922), specifically pp.18-21 for administration and planning after the Severan Age. Also see Coarelli "L'edilizia pubblica a Roma in etá tetrarchica," in Harris 1999, pp23-33. For the organization and distribution of Roman offices, see Homo (trans. Dobie) *Roman Political Institutions: From City to State*, London: Routledge, 1996 (orig. pub. 1929), specifically pp.277-289 for centralized power administration in the later Empire. For make-up of Roman labor forces, interpretation of census data, and available professional labor force for the early Empire, see Brunt *Italian Manpower 225 B.C. – A.D. 14*, Oxford: Oxford University Press, 1971. For a general discussion of material supply in the Roman Empire, see Garnsey and Saller *The Roman Empire: Economy, Society, and Culture*, Oakland: University of California Press, 2015, specifically Chapter 7 pp. 109-126 on "Supplying the Roman Empire."

The antique Roman construction process was possibly more complicated, more poly-modal, and better organized than most that had preceded it in the history of construction.[64] Roman projects required both the succinct coordination demonstrated at the Egyptian pyramids and the assiduous detailing displayed at Greek temples. Prior building endeavors may have been larger in scale or more precise in task, but some Roman work sites simultaneously employed as many as five or six specialized labor forces to assemble and complete a monument.[65] Roman laborers, materials, and supplies were retained in a precise hierarchy to speed the work along and underscore the level of order desired from such a massive workforce. In addition to the tacit organization of the site, the builders had to coordinate the many disparate types of materials that constantly arrived from their far-flung sources.[66] Some materials, like machinery parts, ropes, and capstans, were found in storerooms of the city's construction guilds, and other materials, like brick and mortar, were carted in from the surrounding countryside. Still other materials, like marble monoliths and massive larch timbers, had to be procured from quarries and forests at the far reaches of the Mediterranean Sea.[67] Each of these elements in the material supply chain came

[64] Large-scale construction in Rome has few rivals in antiquity, in terms of size, complexity, and sheer number of projects. The population and topographical density of the Imperial City necessitated dozens of new buildings for each decade of the first century CE, and the continual maintenance and restoration of the total building catalogue of Rome is innumerable. For the closest comparison to size and scale of building in the Western world, cf. Clarke and Engelbach 1990 for the Egyptian construction process. For suitable comparisons in the Greek world, see Coulton 1977, and for a specifically urban example considering the construction of the Athenian agora, see Camp and Dinsmoor *Ancient Athenian Building Methods,* Athens: American School of Classical Studies at Athens, 1984.

[65] The specialized labor forces could even number more, but as an example of the minimums necessary to complete the work specific to the Basilica of Maxentius, the site would require teams for demolition, excavation, foundation, concrete masonry, brick-working, and finishing. The hypothetical numbers for labor forces are estimated from man-power requirements at the similarly-scaled Baths of Caracalla in DeLaine 1997, pp175-182, of which the specific tasks are listed as Terracing, Foundations, Substructures, Central Block Construction, Central Block Decoration, Marble Floors, etc.

[66] See DeLaine "The Supply of Building Materials to the City of Rome," in Christie ed. *Settlement and Economy in Italy, 1500 B.C. to A.D. 1500: Papers of the Fifth Conference of Italian Archaeology, Volume 41 of Oxbow Monographs*, Oxford: Oxbow Books, 1995: pp554-562.

[67] Examples here include Proconnesian marble from the island of Marmara in the Hellespont and larch timbers from the Alpine province of Raetia.

with its own category of infrastructural networking, and sometimes its own classifications and specificities.

As a direct result of the number, variety, and sometimes unwieldy nature of building materials, transport mechanisms, lifting machines, and staging areas needed to be seamlessly choreographed. The most difficult and unwieldy of loads would be handled by treadmill cranes, as illuminated in a scene on the Haterii Relief (see Figure 6). Additionally, builders had to account for the level of impact that each individual task would have on the dense and bustling city, and ascertain the possible degree of disruption.[68] Roman workmen were dutifully trained and exceedingly skilled at deploying certain logistical prowess in their building endeavors, which resulted in the cultivation of several large-scale building typologies during the Empire.[69] The systemic development of Rome's construction industry, technological acumen, transportation facilities, and regulatory mechanisms created a cohesive network able

Figure 6: Haterii Relief. "Construction of a Mausoleum," from the Tomb of the Haterii, Via Labicana, Rome (Late 1st-c. CE). Musei Vaticani, Rome.

[68] See Ward-Perkins 1994; relevant sections include the setting up of the Augustan Forum on pp33-44 and expansions by the Tetrarchy through Constantine on pp417-428; also see Carcopino (trans. Lorimer) *Daily Life in Ancient Rome: The People and the City at the Height of the Empire*, New Haven: Yale University Press, 1940, for a discussion on the Roman city center.

[69] The Basilica of Maxentius was a late Imperial entry in a distinguished list of Roman concrete-vaulted *frigidarium*-style halls, and the earlier bathing complexes of Trajan, Caracalla, and Diocletian served as benchmarks for the progression of this particular large-scale building typology. For the development of the *thermae* complex, see Yegul *Baths and Bathing in Classical Antiquity*, Cambridge: The MIT Press, 1996, and for specifics about the Baths of Caracalla, see DeLaine 1997 pp.13-16. The Basilica of Maxentius is somewhat unique in its use of the *frigidarium* hall outside of the context of a *thermae* bathing complex, and important to the context of this study in that it is sited towards the center of the city of Rome.

to be revived at the most vital moment.[70] The fluidity of this system produced the Basilica of Maxentius and a host of other Imperial projects in the center of Rome in the early 300s C.E.

A sustained arousal of activity in the city center necessitated a constant utilization of the various Roman building industries, and created an inherently interesting microcosm of the networks of Roman construction infrastructure. For the most part, the infrastructure is wholly flexible, but at some times the formal structure of such projects can also be dictated by its means. Specifically, the Basilica was able to be completed efficiently because of its reliance on the brick, concrete, and marble networks that both fed its material structure and dictated the size, shape, and disposition of its elements. The legacy of Imperial Roman architecture remained intact because of its reliance on several branches of its construction infrastructure, an assertion reflected by its principal monuments, like the Basilica of Maxentius.[71]

The Imperial Roman construction process and technique has been continually problematized by a series of issues, including the relative scarcity of ornamental materials, the proportional relationships between material transport and available avenues of dissemination, and the absence of mechanization.[72] Nevertheless, the increased reliance on multi-faceted infrastructural networks continued to allow for the efficient completion of monumental building

[70] See above sources for regulatory management, Robinson 1994 and Homo 1996. These infrastructural networks, and their appropriate organizational agents (municipal and international), functioned with such precision that they were able to quickly execute a variety of tasks in an environment of political upheaval, natural disaster, and geographically confined space.

[71] The success of such projects is noted in Boethius *Etruscan and Early Roman Architecture*, New Haven: Yale University Press, 1994 (orig. 1970), Ward-Perkins 1994, and Wilson Jones 2000.

[72] Scarcity of materials and transport peculiarities will be discussed further in following passages of the current chapter. For a discussion of technologies in the absence of mechanization, consult, among others, the relevant sections of Fitchen 1986, pp3-12; Landels 1978, pp9-33, 186-198; Hodges *Technology in the Ancient World*, London: Allen Lane The Penguin Press, 1970, pp177-205; White *Greek and Roman Technology*, London: Thames and Hudson, 1984, pp9-17; Humphrey, Oleson, and Sherwood eds. *Greek and Roman Technology: A Sourcebook*, London: Routledge, 1998, pp xv-xxiii; Cuomo *Technology and Culture in Greek and Roman Antiquity*, Cambridge: Cambridge University Press, 2007, pp131-164; and Mark ed. *Architectural Technology Up To the Scientific Revolution: The Art and Structure of Large-Scale Buildings*, Cambridge: The MIT Press, 1993.

manufacture.[73] Over the course of the Late Republican and Early Imperial eras of Rome, these networks slowly and deliberately integrated to create a fluid system for building in both the capital city and its outlying territories. Perhaps the largest difficulty in elucidating the symbiotic infrastructural networks of construction is a prior reluctance in ancient scholarship to admit their importance. Specific technologies and techniques are well understood, but an explicit piecing-together of the disparate nodes and vectors of infrastructure has been a somewhat recent development. As mentioned earlier, the analysis of ancient monuments has been inadequate when it comes to assembly, and this circumstance has led to archaeological and virtual reconstructions of buildings in their completed state, with no focus on the processes of construction or destruction.[74]

The literature on this subject is both broad in scope and remarkably fixed in practical applicability, which is probably due to the gradual increase in experimentation and hypothetical speculation in the field of classical scholarship.[75] Accordingly, the direct link of building technique to infrastructural networks is only infrequently alluded to in footnotes of expansive

[73] As an investigation into the presupposed efficiency of Roman building, see Dessales "Not built in a day: awareness of vulnerability and construction techniques in Roman times," in Carvais et al eds. *Nuts & Bolts of Construction History: Culture, Technology, and Society*, Paris: Picard, 2012, pp471–77.

[74] This refers directly to circumstances including drawn two-dimensional images and digitally reconstructed three-dimensional models that continue to show buildings only in their finalized built form, and never as a work-in-progress. As mentioned above, studies such as Lancaster 1999 and Taylor 2003 were among the first to represent buildings in-progress in illustrations. Digital reconstructions of architecture have not addressed the appearance and treatment of construction until recently, including illustrations done by Sahotsky in Favro's article investigating Severan-era construction traffic in Laurence and Newsome 2011.

[75] The slow encroachment of speculation into the realm of classical archaeology is notable for its relative absence in architectural studies until Brown and MacDonald. As mentioned in the first chapter, projects by DeLaine, Favro, Lancaster, and Taylor have advanced the methodology, and recent advancements in experiential theory have been posited in the field of Roman architecture by Laurence and others. The recent interest in experimental study, combined with the rise in applicability of digital reconstruction (as exemplified by projects like Digital Augustan Rome, Rome Reborn, and the Stanford Digital Forma Urbis Romae Project), has made studies like this dissertation possible. There also seems to be a fundamental difference in the acceptability of these speculative approaches in architectural history studies as opposed to field archaeological studies, which by necessity employ differing methodologies. The theoretical base introduced here is thus more likely to have corollaries in experimental archaeology.

studies dealing with archaeological metadata, and seldom applied to the construction of specific monuments.[76] Only recently have studies on construction technique been supplemented by investigations concerning the archaeology of Roman infrastructure, including seminal works on streets and traffic by Laurence, Poehler, and van Tilburg, and the ancient marble trade by Fant, Pensabene, and Ward-Perkins.[77] Another source that will inform a study of Roman infrastructural networks is commodities management analysis, or the process of developing a systematic approach to the entire usage cycle for a group of items.[78] The group of items in this case will be any and all materials involved in the construction of the basilica, and the "systematic" approach will necessarily be infrastructural in nature. The processes of procuring materials and assembling them on site are also diametrically linked to the basic investigative concepts of architectural energetics and site-catchment analysis.

2.2. Architectural energetics and constraint/bottleneck theory

At its most basic level, the relatively recent archaeological/anthropological discipline of architectural energetics provides a means to translate monumental building into 'labor-time'

[76] A circumstance exemplified in volumes like Lancaster 2005.

[77] Relevant volumes for construction technique include Adam 1994 and Taylor 2003. For recent archaeological studies on Roman streets and traffic, see Laurence *The Roads of Roman Italy: Mobility and Cultural Change*, London: Routledge, 1999, Poehler "Romans on the Right: The Art and Archaeology of Traffic" *Athanor* 21 (2003): 7-15, and Van Tilburg *Traffic and Congestion in the Roman Empire*, London: Routledge, 2007. For ancient marble trade, see Fant ed. *Ancient Marble Quarrying and Trade*, Oxford: B.A.R. International Series 452, 1988, Pensabene "La Via Del Marmo: Produzione, Commercio e Consumo dei Marmi Nella Roma Imperiale," *Archeo* 168 (Feb 1999): 53-81, and Ward-Perkins *Marble in Antiquity: collected papers of J.B. Ward-Perkins*, Rome: British School at Rome, 1992.

[78] See the recent study of commodities management in Coyne et al. *Supply Chain Management: A Logistics Perspective*, Stamford: Cengage Learning, 2009, relevant sections include "Transportation: Managing the Flow of the Supply Chain" and "Sourcing Materials and Services;" specific definition taken from U.S. Department of Defense website at http://www.acq.osd.mil/log/sci/com_mgmt.htm. Studies pertaining to Roman commodities management and analysis of commodities in their markets include Temin *The Roman Market Economy*, Princeton: Princeton University Press, 2013, essays by Bowman and Wilson, Lo Cascio, and Jungman in Bowman and Wilson eds. *Quantifying the Roman Economy: Methods and Problems*, Oxford: Oxford University Press, 2009; also see the relevant building industry section of DeLaine's article in Coulston and Dodge 2000.

estimates.[79] The field has been developed and defined by Eliot Abrams in several studies on ancient Mayan building, and based on the anthropological exploits of Charles Erasmus and Bruce Trigger in the Americas and ancient Egypt.[80] Energetics is not only useful for the designating of specific monetary costs of building, but it also allows for the articulating of hierarchical power structures within construction labor and the forecasting of laborer behavioral patterning. Abrams and Bolland suggest that energetics modeling can hypothetically explain the organization of labor, the allocation of workers, the articulation and ordering of tasks, and possibly the larger economic structure of the entire project.[81] The concept of translating architectural building into units of power, energy, and structure has proven useful in an ancient Roman context, as several ideas of cost and material estimates are central to DeLaine's study on the Baths of Caracalla.[82] Architectural energetics contains several concepts that are central to the understanding of labor organization, and I will apply the overall methodology to material infrastructure in the current chapter and site management in Chapter 4.

Monumental building has the capacity to reflect innate cultural information, from the aforementioned political symbolism and changing building aesthetic to more complex ideals of

[79] Abrams and Bolland "Architectural Energetics, Ancient Monuments, and Operations Management," *Journal of Archaeological Method and Theory* 6, no. 4 (Dec. 1999): 263-291, p263.

[80] 'Architectural energetics' as a term was initially coined by Abrams, who admits in Abrams and Bolland 1999 p269 that "a quantified approach to architecture has a rather long history in archaeology, with the idea that ancient buildings are in some way reflective of political power and labor access is evident in the early writings on many ancient societies." For other seminal works by Abrams, see Abrams "Economic specialization and construction personnel in Classic period Copan, Honduras," *American Antiquity* 52, no. 3 (1987): 485-499; Abrams "Architecture and energy: An evolutionary perspective," in Schiffer ed. *Archaeological Method and Theory Volume 1*, Tucson: University of Arizona Press, 1989, pp. 47-88; Abrams 1994. For anthropological studies by Erasmus and Trigger, see Erasmus "Monument Building: Some Field Experiments," *Southwestern Journal of Anthropology* 12 (1965): 419-442; Trigger 1990; Trigger *Artifacts & Ideas: Essays in Archaeology*, New Brunswick: Transaction Publishers, 2003; Trigger *Early Civilizations: Ancient Egypt in Context*, Cairo: The American University in Cairo Press, 1993: specifically, pp74-81.

[81] Abrams and Bolland 1999, p263.

[82] DeLaine 1997, pp103-130 for Severan era; also see Thornton and Thornton 1989, pp15-30 for Julio-Claudian projects.

engineering standards and technological capabilities. In order to sufficiently apply energetics to a case study of the construction process infrastructures of the Basilica of Maxentius, it is important to understand the fundamental components that drive similar quantitative analyses. The study of architectural energetics is at its core a mathematical calculation based on the requirements of the building site and the appropriate equation built to supply that site with materials and labor. Buildings are then roughly translated into cost estimates based on material expenditures, replication and diversification of tasks on site, and total volume of material used in building.[83] These quantities can be measured or reconstructed, and based on hypothetical experimentation and real observations of building activities. The expected 'cost' of the structure is then subjected to further scrutiny in the form of the Theory of Constraints, which has been derived from the fields of project and operations management analysis.[84]

The Theory of Constraints expands upon the idea of resource scarcity, and surmises that all manufacture is constrained by the availability of supplies and labor, and thus subject to

[83] Abrams and Bolland 1999, p264; the authors acknowledge as well that 'perfect knowledge of all volumes and tasks in the construction process is impossible,' and remains an unreasonable expectation of architectural energetics in an ancient building project, and this is the case in all types of archaeological reconstruction.

[84] Ibid; Abrams and Bolland clarify the idea of 'cost,' stating "Architectural energetics is a method through which buildings or building episodes are quantified in terms of cost, with cost serving as the analytic unit of measurement upon which comparative assessments of power or status within and among archaeological societies are based. Cost is synonymous with 'expenditure of human energy' but is rarely measured as direct physiological output of energy. The total cost of erecting a structure is the sum of a series of discrete but often articulated costs in human labor-time resulting from the performance of that set of behaviors within a construction process. Each of those individual behaviors, such as erecting masonry walls or digging earth, can be inferred through direct scrutiny of the empirical archaeological record of each building," pp264-265. The discipline of operations management that studies the use of physical and human resources in an industrial setting is summarized in Melnyk and Denzler *Operation Management, A Value Driven Approach*, Chicago: Irwin, 1996. For applications of organizational and operational management in Roman studies, see Thornton and Thornton 1989, pp30-40 on administration of public works projects, Harris *Rome's Imperial Economy: Twelve Essays*, Oxford: Oxford University Press, 2011, pp113-146 "Roman Terracotta Lamps: The Organization of an Industry," and Paterson "Trade and Traders in the Roman World: scale, structure, and organization," in Parkins and Smith eds. *Trade, Traders, and the Ancient City*, London: Routledge, 1998. The issue of generating models of efficiency to articulate scarce economic variables of labor, time, technology, and capital is most successfully studied in the field of modern spreadsheet modeling, as exemplified in Plane *Management Science, A Spreadsheet Approach*, New York: Boyd and Fraser, 1994; and Eppen et al. *Introductory Management Science*, Englewood Cliffs, NJ: Prentice Hall, 1993.

infrastructural limitations and organizational decisions that govern production schedules.[85] Identifying the variability and limitations of necessary resources allows an architectural energetics analysis to forecast overall project organization and possible exigencies of scale. Specific constraints on the construction process are important to identify and analyze, as alluded to in this study's introductory remarks concerning the absolute validity of the Basilica of Maxentius as a case study of the Roman construction process. Such constraints can be associated with almost every single aspect of the construction process, including overall time allotment, environmental conditions, political maneuvering, security of site, topographic density, scale of construction, ease of site access, and most prominently the availability of resources. Each factor has a sliding window of efficiency, wherein there are several acceptable values for proficient use of time, labor, and supplies. Any deviation from this situationally-variable window creates a 'cost' deficit, and the subsequent need for reactionary organizational decisions and possible shifting of priorities.[86]

Constraints are inherent to any construction project, but when a specific tangible break to acceptable patterns occurs, it manifests in a "bottleneck."[87] Bottlenecking occurs when either a surplus or deficit of a resource manifests somewhere in the construction process. This manifestation may be a result of improper allocation or insufficient availability of resources, or gross misjudgment of any of the construction process' infrastructural networks. The relative

[85] Abrams and Bolland 1999, p272. The Theory of Constraints is posited by the study Goldratt and Cox *The Goal*, Great Barrington, MA: North River Press, 1992; and elucidated in Dettmer *Goldratts Theory of Constraints*, Milwaukee: ASQC Quality Press, 1997.

[86] Cost and benefit analysis has been native to mostly economic study in past scholarship, but a more recent trend indicates that architectural energetics and economic theory can be successfully intertwined. Both branches of study use similar terminology, and sometimes follow the same lines of thinking, while not obviously alluding to each other. For example, see the study Buenstorf 2004, pp10-11, specifically the discussion of 'energy in economic theory,' where the author elucidates cost-share of energy, resource and environmental economics, industrial organization dealing with market structure, pricing, and regulatory issues, theoretical work on exhaustible natural resources, and empirical study of the interrelations between economic growth and energy use.

[87] The concept of the construction "bottleneck" is introduced in Abrams and Bolland 1999, p273.

efficiency of the construction process, and indeed the success of the entire symbiotic relationship between the process and the city, can be continually judged by the existence or eliminating of bottlenecks. The possibilities for bottlenecks are magnified in large-scale concrete vaulted construction, due to the quantity and variety of materials required simultaneously, and further complicated by the myriad overlying infrastructures of 4th century Imperial Rome. Each networking artery or node of the city was consistently occupied by several different supply processes, including brick, marble, stone, timber, implements, tools, and labor itself.[88]

Labor and materials are inextricably linked at building projects, and bottlenecks can mar any construction process if an inaccurate number of workmen have been allocated to perform any high-energy task. Brick-faced concrete in itself relies on a coordination of several raw materials and disparate labor forces, and both a seamless organizational schedule and precise spot adjustments are needed to prevent bottlenecking.[89] No construction project can afford a scenario where 10,000 bricks are unloaded onsite several months early, or one in which dozens of bricklayers are hired with no supplies to work. The tasks fulfilled and the ordering applied inherently matter to the efficiency of the construction process. Accordingly, monumental architecture can be studied through the lens of building technique and engineering tasks to further understand the laborers that lent their knowledge and skill to each construction project.[90]

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[88] For a further discussion of networking dynamics, cf. Barabasi *Linked: The New Science of Networks*, New York: Basic Books, 2002 and Barabasi *Linked: How Everything is Connected to Everything Else and What it Means for Business, Science, and Everyday Life,* New York: Basic Books, 2014.

[89] The similar example of transporting stone was posited by Abrams and Bolland 1999, p273.

[90] Trigger 1993, p75.

2.3. Labor networking infrastructure, administration, and communication

Physical building materials remain the highest volume 'cost' for construction, but the precise deployment of various labor infrastructures and the inherent communication between them remains integral to actual construction completion.[91] Roman labor networks were theoretically managed by the *collegium fabrorum tignuariorum* (*collegium*), and individual workmen were coordinated into smaller and undoubtedly more collegial *decuria* work-gangs.[92] DeLaine specifically offers a debate on whether the *collegium* was colloquially willing to enact any type of guild structure for the benefit of members within their respective trades, and it is therefore unknown whether the *collegium* acted in a bureaucratic manner to arrange *decuria* and distribute them to specific work sites.[93] Although there is little evidence for the overall administration of daily labor tasks in any large-scale architectural construction in Rome, there is little doubt about its necessity.[94] Several notable Roman projects have been theorized to employ as many as 5,500-13,000 laborers, and a sustained and judicious hierarchy of organization must have been inherent to this scale and diversification of labor.[95] Pearse provides an assessment of

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[91] This argument echoed in the relevant section of Fitchen 1986, specifically p50.

[92] The widest selection of evidence of *collegia* comes from Ostia and Lanuvium, as in CIL XIV 2112 = ILS 7212, and other inscriptional evidence is provided by the fragmentary statue of the collegium of Aesculapius and Hygia CIL VI 10234 = ILS 7213, as well as fragments from water-carriers and fullers *collegia* in Rome, CIL VI 10298 and CIL VI 266. It has been debated in scholarship (see next note) whether the *collegium* can be considered as a unifying organizational force for Roman construction workers; the *collegium* was extant during the Imperial era, but little is known about its hierarchy. Vitruvius 7.1.3 and 7.3.10 makes mention of the *decuria* work-gangs in practice; *decuria* are also mentioned in Statius *Silv*. 4.3.40-58.

[93] DeLaine 1997, p204.

[94] This lacuna is noted by several scholars, see Taylor 2003, Anderson 1997, Robinson 1994, Gros 1978. The most reliable ancient source, Vitruvius, also remains silent on the communication between building agents. A discussion of the scant archaeological evidence will be carried out in the relevant section of Chapter 4.

[95] Of the few ancient Roman projects that have estimated totals of laborers, the numbers are still very fluid. In DeLaine 1997, p203, the author cites a critique of an estimate given by Suetonius *Claud*. 20.3 that the Fucine Lake project may have employed 3,000 workers over 11 years (although Suetonius says 30,000), and that the digging of the harbor at Ostia either required 2,000 oxen and 4,000 men, or 5,500 men, over the course of 10 years. Also see Thornton and Thornton 1989, pp57-76 for estimates at the draining of the Fucine Lake, and pp15-30 on manpower estimates and work units for Julio-Claudian building programs. DeLaine's calculations for the Baths of Caracalla indicate that at the height of construction in the year 213 CE, the possibility exists that the project employed 13,100

the evidence of procedural administration of large-scale building projects, and although not surmising a total amount of laborers in the *collegium* or at specific construction sites, he does posit that there may have been an extension of the Republican- and provincial-attested contract system, a major contractor for public works (*redemptor operum Caesaris*), and *curatores* that were engaged on an ad hoc basis for new works.[96]

Even without an explicit understanding of the procedural manual for the recruitment and hiring of labor, it remains quite obvious that the architects and administrators relied on a substantial consortium of both skilled and unskilled workers. The Basilica of Maxentius project may have benefitted from the workforce that existed a decade prior at the Baths of Diocletian, and surely the combinatory nature of projects at the southeastern entrance of the Forum employed every able-bodied laborer in the city.[97] For a comparative figure of total workmen, DeLaine provides an estimate of nearly 20,000 laborers working in Severan Rome during the major building program of the 210s CE, and this figure includes neither the additional 5,000 oxen drovers nor the 1000 or more men employed in the further countryside.[98] It is feasible to

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laborers (p193). Later Delaine suggests that the collegium itself may have had between 10,000 and 12,000 members (p205). For further work-unit estimates at the Colosseum, and subsequent application of energy and thermodynamics to Roman building, see Homer-Dixon 2006, pp31-56.

[96] Pearse *The Organisation of Roman Building During the Late Republic and Early Empire*, Cambridge: unpublished PhD Dissertation, 1974, pp36-56; Pearse cites *CIL* VI 9034 for the *redemptor operum Caesaris* office, and suggests that the overall organization suggests a mode of planning rather than a body of governing officials. DeLaine 1997 p203 recapitulates Pearse's research, and posits that the contract system would surely operate on new construction projects and whenever the task was too large for a permanent slave work force (including most Imperial projects – like the *cura aquarum* for aqueducts). Consult Pearse 1974, pp123-135 for a status of the membership of the *collegium*, and a discussion of the "firms" represented by the membership base.

[97] However, it is unknown where the workers specifically lived, slept, and ate. As mentioned in the discussion of *collegia*, Rome presumably had thousands of skilled workmen that lived in residential areas like the Subura. But this may not have been the extent of the workmen. Some labor may have migrated to Rome specifically for the work, and if so, may have been put up in workmen's housing on site or near the site. In this case, the scope of the architectural projects would widen, as temporary or permanent housing added to the energy cost of the project.

[98] DeLaine 1997, p199; even a total number of laborers close to 25,000-30,000 is quoted by DeLaine as probably "still a low figure," because of the other skilled workmen like sculptors, glaziers, mosaicists, bronze-smiths, leadworkers, and transporters that are more difficult to quantify. These numbers are feasible though, judging by the analysis of the collegium numbers conducted by Waltzing *Etude historique sur les corporations professionelles chez les Romains*, Louvain, 1895-1900, II p118 and IV pp713-714. This study cites *CIL* VI 1060 during the Severan age,

estimate that 4-6% of the presumed population of Rome was employed in the workforce during a period of great building activity, and the majority of these laborers made their home within the city or the immediate periphery.[99] Even the quarrymen and transport drovers that plied their craft in the roughly 6km radius from the Aurelian Walls to the south may be considered in the immediate milieu of Rome's construction activity. The infrastructure of labor radiates even further when considering the boats of the Tiber, the transport ships of the Mediterranean, and the stone quarries of Rome's provinces. Each resource element demanded the requisite stratified and organized labor network. According to a supervening energetics analysis that requires a zero-sum calculation for total energy, even the workmen's tools, food, and clothing are retained in the production process. The aggregate of labor infrastructure thus demonstrates that the construction process and the contextual urban environment must be completely symbiotic in relationship, as the networking pathways for labor workmen and general population serve an immediate dual function.

2.4. Site-catchment analysis in explaining procurement models

Site catchment analysis provides another useful tool for investigating resource production and procurement apart from labor, but along similar infrastructural guidelines. The demarcation of a "site catchment" is imperative in defining the total limits of several key entities, and emphasizing the intersections between the organisms of the construction process and the urban environment. Vita-Finzi and Higgs initially defined site catchment analysis as "the study of the

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and supposes that there may have been 1300 men with collegium membership, each of which may have represented a "firm" of at least 8-10 men.

[99] Figures initially proposed in Brunt "Free labour and public works at Rome," *JRS* 70 (1980): 81-100; analysis continued by Garnsey "Independent freedmen and the economy of Roman Italy under the principate," *Klio* 63 (1981): 368-70, and Skydsgaard "Public building and society," *AnalRom* Suppl. 10 (1983): 223-227. Brunt et al propose that 16th century Rome employed 6% of the population to work on new St. Peter's, and DeLaine 1997, p201 statistically calculates that at least 4% of the population was employed in Severan Rome.

relationships between technology and those natural resources lying within economic range of individual sites."[100] Since this foundational article, the field has developed into a multi-faceted interrogation of the total area from which the inhabitants of a specific site derived resources, and which locational processes had been employed to procure them.[101] The definition of a site catchment has been refined to include concepts fundamental to the relationships between resources and location, including resource usage as a distance-dependent variable relative to the site, marginal-costs, energy availability and expenditure, optimization of energy in disparate resource procurement, the criterion of least effort, optimization strategy, and quantification of work expenditure in transport costs.[102]

Early site catchment analyses were located in studies of prehistoric archaeology, but the capability for widespread legibility has been readily identified in several of the findings. Prehistoric peoples realized cost/benefit ratios, played out scenarios that minimized the ratio of energy expended to energy procured, and were willing to pay higher prices for some resources than they were for others.[103] Each of these concepts will be applied in an increasingly cross-disciplinary way, as principles of cost and energy expenditure have been proven successful when

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[100] Vita-Finzi and Higgs "Prehistoric economy in the Mount Carmel area: site catchment analysis," *Proceedings of the Prehistoric Society* 36 (1970): 1-37, p5.

[101] Roper "The Method and Theory of Site Catchment Analysis: A Review," *Advances in Archaeological Method and Theory* 2 (1979): 119-140, p120, and Ericson and Goldstein "Work Space: A New Approach to the Analysis of Energy Expenditure Within Site Catchments," *Anthropology UCLA* 10, nos. 1&2 (1980): 21-30.

[102] The best summary of these developmental concepts is found in Ericson and Goldstein "Work Space: A New Approach to the Analysis of Energy Expenditure Within Site Catchments," in Findlow and Ericson eds. *Catchment Analysis: Essays on Prehistoric Resource Space*, *Anthropology UCLA, Vol. 10 Nos. 1 & 2,* Los Angeles: Dept of Anthropology UCLA, 1980: 21-30. Concepts introduced are respectively found in Chisholm *Rural Settlement and Land Use*, London: Hutchinson University Library, 1962; Earle "A model of subsistence change," in Earle and Christenson eds. *Modeling Change in Prehistoric Subsistence Economies*, New York: Academic Press, 1980: 1-29; Foley "Space and energy: a method for analyzing a habitat value and utilization in relation to archaeological sites," in Clarke ed. *Spatial Archaeology*, London: Academic Press, 1977: 163-187; Limp "Optimization theory and subsistence change: implications for prehistoric settlement location analysis," paper presented at the Forty-third Annual Meeting, Society of American Archaeology, Tucson, Arizona, May 6, 1978; Zipf *Human Behavior and the Principle of Least Effort*, New York: Hafer, 1965; Von Neuman and Morganstein *Theory of Games and Economic Behavior* (3rd edition), Princeton: Princeton University Press, 1955.

[103] Roper 1979, p121.

utilized outside of the sphere of prehistoric archaeology.[104] Roper suggests that site catchment analysis can be valuable in a variety of studies, including cultural-historical reconstruction, economic feasibility investigation, settlement pattern modeling, and demographic analysis.[105] The addition of energy and constraint theory to a site catchment analysis of the Basilica of Maxentius provides a multi-dimensional diagram of the relationship of worksite-to-infrastructure, or a map for the entire process of construction.

The Basilica of Maxentius is problematized by a geographically substantial and systemically dynamic catchment area, with regard to the size and type of materials utilized, and the extant construction infrastructure that fed supplies and materials from provinces distributed around the Mediterranean. Site catchment analysis assumes that a gradual increase in distance from each procured resource to the locus of the project leads to a corresponding stimulation in amount of energy exhausted.[106] Thus the entire construction project may be considered as a function of its largest or furthest distributed infrastructural network. The largest volumetric contribution to the Basilica of Maxentius is the hundred thousand bricks characterizing its walls and vaults, but the most spatially diverse and seasonally complicated material supply is the vast marble trade network.

2.5. Marble trade system infrastructure: commodification and contracts

In order to erect a building the size of the Basilica of Maxentius in a relatively short period of time, the Romans employed a vast system of material distribution, including

[104] Cf. Fitchen 1986 and DeLaine 1997.

[105] Roper 1979, p135.

[106] Ibid p120; also commented on by Ericson and Goldstein 1980, pp21-23.

procurement of resources from local and peripheral suppliers.[107] The Basilica's site catchment is principally defined by local materials produced in large quantities, but the showcasing of luxury marbles on both interior and exterior required a lengthy international travel cycle. The Roman Imperial marble trade infrastructure was characterized by an extensive diversity of supply, a complicated procurement model, a necessarily far-flung and deliberate transport system, and a comparatively brisk rate of production and distribution. The display of exotic marbles had been a source of pride for the Roman emperors for centuries, and effectively demonstrated their dominion over the areas of marble production.[108] When Augustus left Rome a "city of marble" in the early 1st century C.E., he essentially forecasted three centuries of colossal stone construction in the capital of the empire.[109] Massive monolithic columns were a particular favorite of the Roman Emperors, and although these marbles were a symbol for the domination of Rome, an equal degree of power was displayed in their transport and erection. Adam states that the astonishing technical accomplishment in the handling and transporting of these marbles is only overshadowed by the rendering of such grand achievements commonplace by the Romans.[110]

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[107] As mentioned above, the basic materials needed for such a substantial project in 4th century Rome included brick, tufa, and stone for the foundations and structures, lime and pozzolana for mortar production, metals and marbles for decoration, and timber for scaffolding, formwork, and construction implements. These materials will also be introduced further in the following sections. Adam 2004 p102-157; the first three chapters devoted to particular types of construction are 'Construction Using Large Stone Blocks,' 'Structures of Mixed Construction,' and 'Masonry Construction;' this included brick, concrete, and marble. The topic of overall material proceurement is also investigated in the seminar essay Sahotsky "The Infrastructural Networks of Roman Construction: A Case Study Based on the Basilica of Maxentius" presentation at UCLA AUD, Los Angeles, Fall 2009.

[108] See Fant 1988; Ward-Perkins "Quarrying in Antiquity, Technology, Tradition and Social Change" *Proceedings of the British Academy* 57 (1971): 137-158.

[109] Augustus was famously quoted in Suetonius *Augustus* 28 as saying 'I found Rome built of bricks; I leave her clothed in marble,' insinuating that he had jump-started the imperial marble industry and used it extensively in the capital city. It has been noted that, at the time of Augustus, most buildings were simply decorated with marble revetments, and were not structurally composed of marble; this circumstance would be exhibited later, during the reigns of Hadrian, Trajan, and others.

[110] Adam 1999, p24.

Pliny records a famous example of 38-foot Lucullan marble columns being dragged through the center of Rome to a private residence on the Palatine Hill, with no secrecy or concealment.[111]

By the 4th century, Rome had control of most of the territories that housed the great quarries of the Mediterranean world, and owned more than a simple share of those which they controlled.[112] The infrastructure of this trade was intact regardless of the derelict status of possible shipping destinations.[113] Workmen labored in the quarries, on the ships of the trade routes, at the ports of Ostia, and at the Emporium marble yards almost the entire year, and were able to provide a variety of stones in a fantastic abundance.[114] Fant suggests that by the Antonine period, quantities of marble shipped to Rome reached several thousand blocks per year.[115] Ward-Perkins states that the imperial system of quarries, operating continuously rather than fulfilling orders as they arrived, had produced so much marble by the Antonine period that the rest of antiquity, and indeed later ages, never used it up.[116] Pensabene even referred to the marble inventories as if they represented a fiscal reserve.[117] By the Maxentian era, quarries were in

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[111] Plin. *HN* 36.6, "Were not the laws silent also when the largest of those columns, which were each fully 38 feet long and of Lucullean marble, were placed in the hall of Scaurus' house? And there was no secrecy or concealment. A sewer contractor forced Scaurus to give him security against possible damage to the drains when the columns were being hauled to the Palatine. Would it not have been more expedient, therefore, when so harmful a precedent was being set, to afford some security for our morals? The laws were still silent when these great masses of marble were dragged to a private house past the earthenware pediments of temples!" In Pliny's summation, his most pressing concern is the preservation of Roman "morals" when these marble monoliths destined for a private house passed by terra cotta temple fronts.

[112] Ward-Perkins 1992, p24.

[113] See Fant "The Roman Emperors in the Marble Business: Capitalists, Middlemen or Philanthropists?" in Herz and Waelkens 1988, pp147-58; and Fant "Ideology, Gift and Trade: A Distribution Model for the Roman Imperial Marbles" in Harris 1993), pp145-70.

[114] Pensabene 1999, and Fant "Rome's Marble Yards," *Journal of Roman Archaeology* 14 (2001): 167-198, where Fant discusses "a picture of busy marble yards processing thousands of quarry artifacts a year, meeting imperial building demands and selling into an inexhaustible private market."

[115] Fant 2001, p172.

[116] Ward-Perkins 1992, p28.

[117] Pensabene "Le Vie del marmo," *Itinerari Ostiense 7* (1995): 156-158.

continuous use to furnish stones for the four separate provincial capitals of the Tetrarchy, and shipments were constantly crisscrossing the Roman-controlled Mediterranean.[118]

Figure 7: Satellite view of Mediterranean Sea, depicting the quarries and ports that supplied marble to the Basilica of Maxentius. GoogleEarth project conducted by author. Map data: Google, Landsat.

In Tetrarchic Rome, common marbles like Carrara could be provided at a moment's notice.[119] But, if the marble was exotic or hard to work, then a degree of foresight would be called into play. Large or diverse orders may have taken years for the overseas marble network to complete its dynamic cycle. The Basilica of Maxentius required decorative elements from three continents, and marbles found on site included pavonazzetto, africano, and proconnesian from Anatolia, cipollino and portasanta from the Greek islands, grey granite and red porphyry

[118] Cf. relevant essays 'Geology of Greece and Turkey: Potential Marble Source Regions,' 'Quarries and the Marble Trade in Antiquity,' and 'The Roman Emperors in the Marble Business: Capitalists, Middlemen, or Philanthropists?' in Herz and Waelkens 1988.

[119] Maischberger "Some Remarks on the Topography and history of imperial Rome's marble imports," in Schvoerer ed. *Archeomateriaux: marbres et autres roches*, Bordeaux: Universite de Bordeaux 3, 1999, p325.

from Egypt, numidian yellow from northern Africa, and green porphyry from southern Greece (see Figure 7).[120] The comparatively small timetable for the Basilica suggests that the finishing marbles used in flooring, revetments, and façade articulation may have been in inventory at the Emporium supply yards along the Tiber, which Maischberger suggests were without a doubt the largest stockpile of marble in Rome from the Neronian age through the end of the Empire.[121] However, the design plans for the Basilica of Maxentius also called for eight massive marble monoliths, and these columns required a more disciplined level of planning and a dramatic show of Roman engineering in order to take their place in the central hall.[122]

One method of illuminating both the breadth and intricacy of the marble trade infrastructure in the early 4th century is to track the fascinating 2400-kilometer journey of a monolithic 100-ton Proconnesian marble column as it makes it way out of the rock in the Hellespont and arrives at the Basilica of Maxentius at the south end of the Roman Forum. It is unlikely that the eight interior monolithic shafts measuring 1.82 meters at the base and standing 15.72 meters high were found in the storage yards, and these columns would have been difficult to attain at short notice. Although scholars believe that marble columns may have been spoliated during the Roman Imperial era and certainly afterwards, the difficulties inherent in moving such

[120] Giavarini 2005, pp119-120.

[121] Maischberger 1999, p325. Ward-Perkins 1971, p148 states that by the second century the marble yards had built up enormous stocks of common marbles; Fant 2001, pp195-196 states that the blocks and columns are evidence that there was an active workshop near the harbor, not simply a storage yard, and that several columns suggest that the Portus workshop was equipped to do quarry work and to prepare columns for use in specific buildings.

[122] The last instance of columns this size near the city center may have been the monoliths at the Pantheon (11.8 meters and 60 tons) and the Forum of Trajan (at least 8.83 meters in the Basilica Ulpia) in the 2nd century; most of the projects after this date were based in brick or smaller decorative materials (including the city walls of 260, the Curia of 283, and the baths of the 280s).

enormous and unwieldy columns must have presented significant problems in any degree of re-use or procurement, and stretched the effable limits of symbiosis in the city.[123]

Columns of this specificity and grandeur were originally requisitioned from the famous Proconessian quarries in the Sea of Marmara, in the Anatolian Hellespont. The columns probably took almost a year to arrive at their destination in Rome.[124] This estimate includes the initial order sent by messenger across 2400 kilometers of the Mediterranean, the time spent at the quarries readying and loading the product, and the more substantial and careful journey back across the breadth of the sea. The timing of delivery was absolutely crucial, but equally difficult to predict. Any scenario involving the early or late arrival of materials would necessitate an adjustment of schedule, and cost the project money.[125] The construction budget would increase when early arrivals clogged up storage yards, or when tardy materials delayed on-site work. Damaged materials and entire shipments lost at sea were even more costly. Replacement or repair expenditure likely plagued many building projects in antiquity, and Wilson Jones has noted the possibilities for alterations being made to buildings based on the contingencies of lost or damaged materials.[126] In addition, these difficulties existed in tandem with the assumption of a

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[123] A notable Maxentian-era example is the Arch of Constantine (a spoliation of columns rondels, and sculptures). For difficulties maneuvering large marble columns, consult the next chapter on technique and spectacle, also see Ward-Perkins 1971, Fant 1992, Pensabene 1999, Adam 1999. The possibility that the Basilica of Maxentius' interior columns were spoliated from another Roman building will be introduced in the next section, but at present, the inception of the columns at their source is suitable for an investigation into marble trade networking and catchment.

[124] An interesting source for transport throughout the Roman Empire is provided by the Orbis Stanford project, which estimates travel time, distance, and cost throughout the Mediterranean (http://orbis.stanford.edu). This project is useful for estimates, but mostly reliable for human transport and not material shipping. An example of transport from Proconnesus to Rome during the summer season, assuming the cheapest method of travel and a "slow" approximation for a large cargo yields 28.3 days of travel one-way. The fact that a normal cargo ship even at the "slow" designation could never transport 100-ton marble monoliths complicates the equation. Doubling or tripling the trip time may be more accurate, which yields several months one-way. If we add the one-way order in the westerly direction from Rome to Proconnesus, and a suitable time to quarry and prepare the cargo, the total time easily approaches 12 months or more.

[125] An interesting case of the loss of cargo being a tacit concern in Imperial transport is provided in Suetonius *Claud*. 18; the emperor employed state-funded insurance from losing a critical shipment to storms.

[126] Wilson-Jones 2000, pp199-206; notably at the Pantheon.

timely ordering process. Architects or master builders calculated the height and girth needed from each supporting column, and likely discussed this information with their contacts at the marble yards.[127] This combination of issuing orders, knowledge of various quarries and marble provenance, and money changing hands presents an extremely complicated circumstance for a very fine art. Allowing for every variable at issue in placing and receiving purchase orders, the timely fulfillment of any contract could be considered a spectacular feat, if not for the continual precision exhibited each year by the Roman marble trade network. It was this precise system that allowed the Maxentian builders to commission almost 1000 tons of marble from halfway across the known world.

The marble quarries on the island of Proconnesus (or Marmara) were famous in antiquity for their particular quality, and were employed frequently.[128] On this relatively small island, the conspicuous quarries were located directly above the port on a rolling hillside.[129] The quarry masters were continuously at work preselecting blocks in the hillsides and fielding orders, some of which would fill various marble reserves across the Mediterranean.[130] However, it remains unclear whether the quarry could anticipate orders for large monoliths, considering their relative

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[127] It is difficult to ascertain the direct involvement of the designer/contractor and the Emporium supply yards foreman, but the close contact is attested to in the legal record, as discussed by Rainer "Public Building Contracts in the Roman Republic" in McGinn ed. *Obligations in Roman Law: Past, Present, and Future*, Ann Arbor: University of Michigan Press, 2012, pp174-188, and du Plessis "The Protection of the Contractor in Public Works Contracts in the Roman Republic and Early Empire" *Journal of Legal History* 25 (2004): 287-314, p294, among others.

[128] Several famous imperial-age projects employed Proconnesian white marble, a notable example being the Arch of Trajan in Ancona, made solid in solely Proconnesian blocks. Also of note is the preference during the Antonine age for Proconessian marble metropolitan sarcophagi; see Bowersock et al. *Late Antiquity: A Guide to the Post-Classical World*, Cambridge: Harvard University Press, 1999, p560; the authors mention that Proconnesus began another sustained period of supplying white marble to the new capital of Constantinople from the 320s to the late 6th century CE, even remarking that Proconnesian white was the marble of choice for all new building projects.

[129] The quarries were above the port; it is unclear if there was another staging point for the marbles until they set off across the Hellespont and into the Mediterranean. Adam 1999, p23 specifically mentions that the terraced "steps" created by the ordered selection and extraction of blocks in an ancient quarry can sometimes be seen from many kilometers away, contributing to the conspicuous appearance of the island's quarries. Terracing as a technique is expounded upon in Adam's Chapter 2: Materials, with an indicative diagram number 21.

[130] For Roman quarrying technique and jobs of workmen and quarry masters, see Adam 1999, pp21-25.

scarcity even in Rome. If the monoliths were promptly requested, an imperial order would presumably trump any others in the queue, or simply appropriate another order if necessary.

At Proconnesus, a skilled workforce chiseled and readied the 15-meter-long monoliths, sallied them onto tracks, and rolled them down a series of hills via pulleys and other mechanisms to the coastal port (see Figure 8).[131] At several ancient quarries or stone-cutting sites, intermediary stages between rough-cut stone and finished piece can be traced with a remarkable degree of continuity.[132] The specific contract order would most likely stipulate the level of finishing exhibited on the column, although there is no evidence available for the state of the basilica's columns before they would have left Proconnesus. Upon reaching the port, the columns were transferred onto barges, either by rolling, pulleying, or being lifted and lowered by treadmill cranes. The cargo was then readied for its long overseas journey to the Roman port of Ostia. While this first stage succeeds in the commodification of the luxury marbles, the subsequent

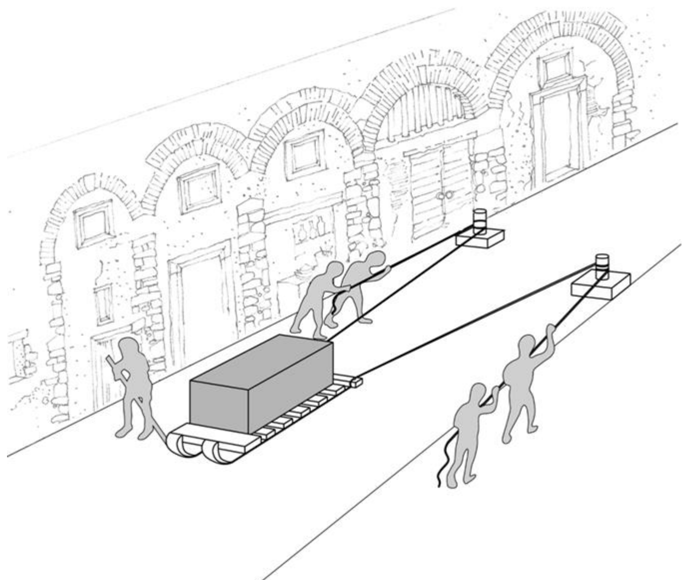

Figure 8: Re-creation of a stone block on a sledge being manipulated down a street using ropes attached to bollards; image used courtesy of Yegül and Saldaña.

[131] Adam 1999, p29; based on research on trilithons at Baalbek. Adam 1999, p20 states that term quarry (*carrier* in French) may derive from the heavy cart designed to transport stones along the tracks leading to or from the source, and see Adam 1999, pp26-29 for technique and visual representations. Also see note 32 concerning mechanisms for loading and transporting materials.

[132] Adam 1999, pp36-37.

phase is defined by a far more perilous journey across infrastructural arteries that will result in their showcasing in Rome.

2.6. Marble trade system infrastructure: overseas and river transport

The Basilica of Maxentius' site catchment extends in this case to the Sea of Marmara in the Hellespont, but in order for the resources to bridge the great distance from origination to destination, the marble trade infrastructure needed to employ a vast overseas transport mechanism. This mechanism was deployed by a variety of trade infrastructures during the Roman period, and all resources not mined or produced on the Italian peninsula probably traversed the Mediterranean at one time or another. The materials for brick-faced concrete construction were for the most part sourced locally, but provisions such as large timbers for centering and scaffolding, and certainly luxury marbles were fabricated in far off shores.

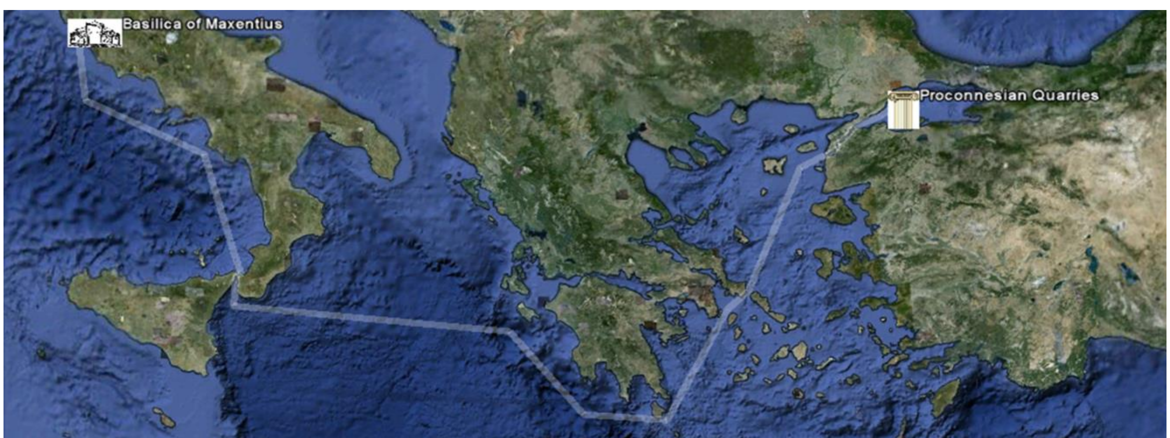

Figure 9: Satellite view showing the 2400 km journey of marble from Proconnesus to Rome. GoogleEarth project conducted by author. Map data: Google, Landsat.

Conveyance by sea was obvious from the island location of Proconnesus, but it must be mentioned that in the case of large stones, sea transport was almost always selected in lieu of land transport. Rockwell pointedly mentions that transportation by water, when possible, easily resolves the problems that the bulk and weight of stone create.[133] Not only can ships carry larger loads, but, as they are not dependent on the quality of roads or geological impediments, they can carry it faster and with a great deal less manpower than any form of land transport. Even with these obstacles eliminated by using sea transport, transporters still were faced with an exceedingly long voyage through well-charted but seasonally temperamental waters.

The 2400 kilometer journey of the eight monoliths through the Mediterranean is certainly estimated at minimum, and has been affirmed by several investigations by the author using the Stanford Mapping Project, Google Earth, and GIS platforms (see Figure 9).[134] This distance assumes no additional stops at auxiliary ports, and a streamlined trip through the Aegean islands, around the tip of the Peloponnesian Peninsula, and through the Straits of Messina. It is difficult to ascertain whether an important imperial marble shipment would have been routed directly to its destination, or if it completed extra stops, which would have been the norm for large trade ships carrying standardized commercial cargoes.[135] Vessels of great size were purpose-built, provisioned frequently, and likely sailed the shoreline for as long as possible to take advantage of the few ports that were complex enough to accommodate such large ships. Casson suggests that ships in the Mediterranean also preferred to hug the coastlines, in order to avoid being caught by storms.[136] If these variables held, the total distance estimate would necessarily increase by

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[133] Rockwell *The Art of Stoneworking: A Reference Guide*, Cambridge: Cambridge University Press, 1993, pp97; it is also estimated that carriage by land almost doubles the cost of carriage over water.

[134] Studies were conducted with real-time software platforms GoogleEarth and ArcGIS, and relied on accurate modern data for distances between quarries and ports. Most of the quarries queried still exist to the modern era, including that of Proconnesus. Thus, the modern distances covered will sufficiently stand in for the ancient distances, allowing for a very small degree of error. The Stanford Mapping Project (http://orbis.stanford.edu), introduced above, was also employed for tests, although several variables remain hypothetical according to the data allowed in the platform regarding material transportation possibilities.

[135] Casson *Ships and Seamanship in the Ancient World*, Baltimore: Johns Hopkins Press, 1995, pp171-189; this is especially noting the unpredictable nature of the Mediterranean Sea, and the need for safety as well as maximizing profits from shipping goods.

[136] Casson 1995, pp280 and 337, sites examples of ships hugging coasts for safety.

several hundred kilometers. Scholars estimate that the Mediterranean was passable by ship during about half of the year, and with such valuable cargo, the transporters must have planned their voyage accordingly. Delaine suggests that long shipping voyages across the sea were impossible from early November to early March and deemed dangerous from late September to late May.[137] This would leave only a four-to-six-month window where the seas were sufficient for conveyance of large marbles.[138] When dealing with such a comparatively small shipping window, the laborers in the quarries must have been extremely efficient, and the progress legitimately controlled. Energy costs would rise significantly if the cargo was ready prematurely, because the heavy marbles would then be sallied into and out of storage. Conversely, if the transport ships arrived without a readied product, they would either be forced to move on or provision the crew for an additional unspecified time period.

Figure 10: Shallow barge apportioned for ferrying an obelisk on an Italian coast. Galleria Carte Geographica (late 16th c. CE), Musei Vaticani, Rome.

Even assuming that the entire product was ready at the exact moment that the schedule had dictated, the marble porters must

[137] DeLaine 1997, p99; according the Vegetius *Military Science* 4.39, long voyages across open seas were navigated by the stars, and were restricted to these months, "for the power and fury of the sea do not allow sailing during the whole year, but by natural law some months are particularly suitable, some are doubtful, and the rest are unsuitable for fleets." Navigation was "safe" from late around May 27 to September 24. The seas are "closed" from November 11 to March 10. According to Bedon *Les carrieres et les carriers de la Gaule romaine*, Paris: Picard, 1984, pp98-99 and noted in DeLaine 1997, p120, there is evidence of a break in quarry operations at the Saint Beat quarries in the Pyrenees between the Ides of November and the Ides of March. This would indicate a similar pattern of production and transport of large marbles during the working season.

[138] The sailing season is explicated in "10.57 Sailing Season in the Mediterranean," in Humphrey, Oleson, and Sherwood 1998, p443.

still account for all manner of accident or pitfall. The seafloor of the Mediterranean likely holds several marbles that were "supposed" to have adorned temples and basilicas.[139] Indeed, much of the information about the various marble yards of Rome is culled from evidence accidentally dropped into the water before fulfilling its purpose. The mechanisms for loading, unloading, and steadying the cargo were not always totally reliable, and 100-ton marble columns would undoubtedly employ the most diligent planning to ensure their safe delivery. De Souza cites evidence from Mediterranean shipwrecks suggesting that a standard cargo ship at the height of the Roman Empire carried about 250 tons, which would necessitate at least four separate shipments from Proconnesus to Rome.[140] Splitting up the eight massive columns into multiple shipments also would assure that not all would be lost in a single shipwreck, but did not allay the fear of losing even one item of the important imperial cargo (see Figure 10).

Most cargo ships on the open sea relied on sails for propulsion, as opposed to oars, which created more room on deck, but put the ships at the mercy of the weather. Synesius of Cyrene, the Bishop of Ptolemais in 396 C.E., records an episode of peril while crossing the Mediterranean,

> "As the hours passed, the sea increased continually in volume. Indeed, the hugest waves were actually menacing the vessel, and the very deep was at war with itself. The billows

[139] Ibid. Also evidence from Asgari "Roman and early Byzantine marble quarries of Proconnesus," *ProcXIntCongClassArch* (1978): 476-479; Asgari "The stages of workmanship of the Corinthian capital in Proconnesus and its export form," in Herz and Waelkens 1988: 115-125; Beykan "The marble architectural elements in export form from the Sile shipwreck," in Herz and Waelkens 1988: 127-137.

[140] See De Souza *Piracy in the Graeco-Roman World*, Cambridge: Cambridge University Press, 1999, pp179-203; the analysis during the Pax Romana provides a good summary of the Mediterranean Sea during the Roman Empire, including the security and might provided by Roman dominance of the seas. Consult section 7: Piracy in Late Antiquity for comparanda with Imperial seafaring. Also DeLaine 1997, p108 states that 70-80 ton ships were the most common, 300-400 ton-ships "were not uncommon," and cites evidence from Lucian *Navig*. 5 concerning the existence of "supercargoes" of 1000-1200 tons, but the data do not suggest where or when these ships were employed. It is not at all certain whether supercargo ships would be employed for 1000-kilometer overseas journeys, mainly because of the slow speed and high cost of such shipments. For further discussion of tonnage limits, consult Landels 1978, pp160-164; Pomey and Tchernia "Le tonnage maximum des navires de commerce romains," *Archeonautica* 2 (1978): 233-251; Rogue *Ships and fleets of the ancient Mediterranean*, Middletown: Wesleyan University Press, 1981, pp74-78.

> are under the influence of the wind's force, to which they yield, and with which they battle at the same time, and the oncoming waves fight against those subsiding. To people who are at sea in such a crisis, life may be said to hang by a thread."[141]

On this particular voyage, the passengers were more than once prompted to wear gold pieces around their necks, in order to pay the burial fee to scavenging profiteers upon their imminent death. They were also forced later to run their ship aground, and wait two days until the sea abated before embarking again. This episode illustrates the constant peril faced not only by the passengers, but by the cargo as well. If not managed correctly, ships confronted by a storm of this magnitude could dump their cargo to the bottom of the Mediterranean. The careful ballast weighting employed when ferrying large stone monoliths was a fragile calculation that was affected by even marginal shifts of load. Given the cost of the shipment and the precious nature of imperial cargo, it is likely that marble trade ships obeyed seasonal seafaring charts and were quite orthodox in their routes.

Small to medium-size vessels were probably only crewed by a few dozen boat wrights, and at optimal conditions traveled around 3-4 knots per hour, or 120-150 kilometers, per day.[142] Assuming that larger ships carrying a few of the basilicas columns would conduct themselves at a slightly safer and more manageable pace, it is possible that the vessels may only cover 60-75 kilometers in 24 hours. If the 2400-kilometer trip was subject to any stops or storms, or the course altered to stay closer to the shorelines and away from the open sea, the length may have been protracted as well. Considering all of the possible variables at play in a single journey, all time estimates are cautious at best. One large trade ship may be able to traverse the ancient

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[141] Synesius *Epistolae* 4.

[142] DeLaine 1997, p108; the ship from Synesius' episode was crewed by 13 men. For a discussion of Roman ship speeds and distances covered, consult Throckmorton "Romans on the sea," in Bass ed. *A history of seafaring based on underwater archaeology*, London: OMEGA, 1974; Parker "Classical antiquity: the maritime dimension," *Antiquity* 64 (1990): 335-346; Yeo "Land and sea transport in imperial Italy," *TAPA* 77 (1946): 221-244, p232.

Mediterranean in somewhere between 30 and 60 days. Sending several ships with several columns each may have dominated the entire shipping cycle of four to six months, and this would assume that all eight monoliths were ready for shipment at the beginning of the effective season. The only real "success" for a portage of this magnitude was the arrival of all eight columns, or their ordered replacements, undamaged and unfettered at the Portus marble yards on the banks of Ostia.

Once arriving in Italy, the columns were lifted off the ships and stored temporarily in the marble yards and warehouses of Portus, where they awaited the entire shipment and received further preparations for use in Rome.[143] The ensuing portage up the Tiber River was complicated by seasonal flooding, which may have varied the height or breadth of the river. Given the normal width of the Tiber, Eubanks verifies that the columns must have been unloaded from the larger Mediterranean ships and reloaded onto smaller barges for river hauling.[144] The remaining passage up 30 kilometers of the Tiber was undertaken by river

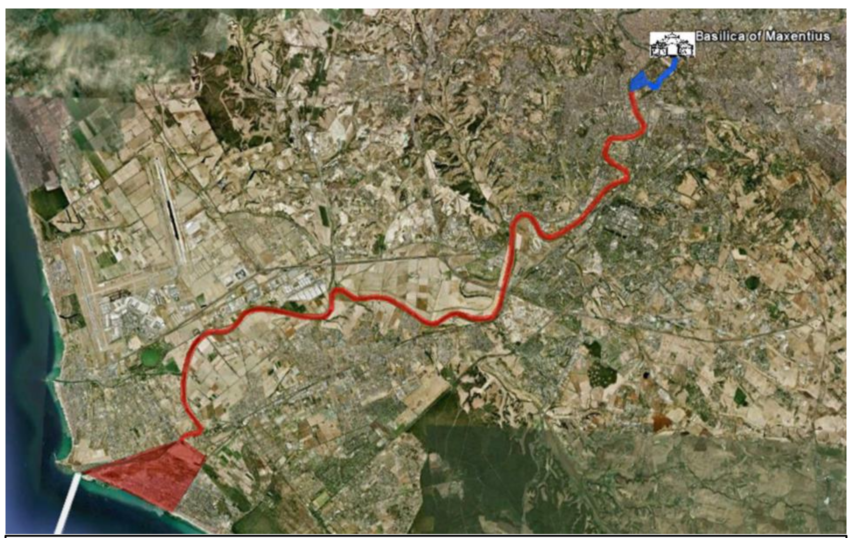

Figure 11: Aerial view of Rome, red represents the Portus yards at Ostia port and the Tiber river conveyance, Blue represents the Emporium yards in Rome, and trip through the streets to the building site. GoogleEarth project conducted by author. Map data: Google, DigitalGlobe.

[143] Fant "The Roman Imperial Marble Yards at Portus," in Waelkens, Herz, and Moens eds. *Ancient Stones: Quarrying, Trade and Provenance: Interdisciplinary Studies on Stones and Stone Technology in Europe and Near East from the prehistoric to the Early Christian Period*, Leuven: Leuven University Press, 1992.

[144] See Eubanks "Navigation on the Tiber," *The Classical Journal* 25, no. 9 (June 1930): 683-695; and DeLaine 1997, pp99-100, 107-108 for the passage up the Tiber River.

boats that probably could only bear the weight of one of the Proconnesian monoliths at a time. Scholars currently believe that barges could only be burdened with 150-200 tons on a large wide river, and suggest that barges on the Tiber may only have held around 70 tons.[145] Given that these particular columns weighed around 100 tons, either the tonnage requirements were relative, or the columns were transported on land from Portus to Rome.

In the event of a river portage, the Tiber barges were facilitated by oxen and guide-ropes which towed the barges against the currents. DeLaine mentions that each river transport required at least a 3-man crew with one pair of oxen and appropriate drover per each 20 tons of portage.[146] The Tiber was thought to be populated by two types of boats, the *lenunculi* flat-bottomed barge and the *naves codicariae* masted skiff.[147] The barges would be employed to porter the cargo upriver towards the center of Rome, and eventually the marbles would reach their next staging point and rest until the final transfer to the building site (see Figure 11). The columns would be unloaded by treadmill cranes or other implements and transferred onto rollers or oxcarts, which would later act as their conveyance to the building site. The Emporium warehousing district, which was the main conduit for all marble and other stones into Rome, was located at a bend of the Tiber southwest of the Aventine Hill, and represented the closest point that barges could get to the inhabited areas of the city of Rome. There were likely other municipal material storage yards used during the Imperial period, but the Emporium was large, organized, and the closest and most convenient to the Basilica of Maxentius.[148]

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[145] Casson "Harbour and river boats of ancient Rome," *JRS* 55 (1965): 31-39, p32; Rickman *The corn supply of ancient Rome*, Oxford: Oxford University Press, 1980, p19; DeLaine 1997, p108.

[146] DeLaine 1997, p108.

[147] Casson 1965, pp35-38, DeLaine 1997, p108; the *lenunculi* are specifically notable from archaeological excavations of Claudius' harbor at Portus. *Naves codicariae* were thought to be suitable for river and coastal work, and were equipped with towing masts.

[148] Stamper *The Architecture of Roman Temples: The Republic to the Middle Empire*, Cambridge: Cambridge University Press, 2005, p192 suggests that the materials for the Hadrianic-era Pantheon may have been unloaded

Even in the event that the columns were ordered directly for the Basilica project, they likely were stored in the Emporium for at least a few days or weeks before they were needed at the site. This furlough would allow the building foremen to plan the specific route through the city, and anticipate any problems with the haul. Depending on the season in which they were ordered, the success of the seaward journey, and the level of the Tiber, the columns would have been fortunate to arrive at the Emporium in less than a year from the date of order. Substantial marbles like this may have been requested well before they were needed on site to avoid any mishaps. The arrival and stockpiling of imported marbles at the Emporium does not signal the termination of the infrastructural connections of the marble trade network, nor does it define the extent of the basilica's total site catchment area. However, this specific stopgap indicates a focal coincidence of both local and imported product procurement systems, and each appropriate labor force. The material storage yards thus act as an expedient pivot point for several networking nodes of construction infrastructure, and successfully outline the symbiotic relationship forged within the context of Rome.

2.7. The interwoven material infrastructures for brick-faced concrete-vaulted masonry

The infrastructural networking built for the import of foreign marbles covered a vast amount of geography in the Mediterranean. But a much more volumetric contribution to Roman architectural building is provided by the dynamic systems of brick-faced concrete-vaulted masonry. Large-scale construction like the Basilica of Maxentius required bricks (*opus*

further up the Tiber River in the Campus Martius near the Mausoleum of Augustus (based on pediment and entablature templates found incised there), which makes logistical sense because of the Pantheon's northern location in the city. These northern storage locations would be impractical for access to the area south of the Forum, which leads to the conclusion that the Emporium must have been used if the columns were direct-ordered for the Basilica of Maxentius project. If they were not, as introduced below, then they may have passed through other storage areas, depending on their specific need, or before later spoliation and transport.

latericium and *opus vittatum)*, concrete (*opus caementicium)*, and substantial wooden formwork.[149] The scale and speed of Roman building underscores the seamless coordination of disparate material networks to function as a singular construction machine without overtaxing the host environment. By relying on the exceedingly efficient Roman industries of brick and

Site Catchment Analysis For Total Materials Used at the Basilica of Maxentius			
Construction Material	Amount	Source	Distance to Site
Total Concrete Masonry	47,500 m³	-	-
BRICKS	11,300 m²	-	-
Clay	5000 tons	As far as Via Salaria	<10km
Wood to Fire Clay	560 tons	Kiln Vicinity	<10km
MORTAR	24,000 m³	-	-
Lime	~ 6000 m³	Tivoli	<35km
Wood to Fire Lime	480 tons	Kiln Vicinity	<35km
Pozzolana	~ 18,000 m³	Ostiense	<8km
Water	~ 8000 m³	Aqueduct in Rome	<1km
Pumice Aggregate	Unknown	Marino	<25km
Tufa Aggregate	Unknown	Fosse Ardeatine	<2km
MARBLE	900 m³	-	-
Proconnesian Monoliths	800 tons	Proconnesus	>2400km
Floor/Wall Revetments	1600 tons	As far as Egypt	>3500km
DECORATION	-	-	-
Addt'l Mortar for Stuccowork	~11-12km	-	-

Figure 12: Chart for site catchment analysis for total materials used at the Basilica of Maxentius. Chart by author.

concrete production, Maxentius was able to complete many of his projects expediently with local materials and proficient workmen.[150] The Basilica of Maxentius in particular was one of the

[149] The best overall scholarly summary of concrete-vaulted construction technique is provided by Lancaster 2005. Also see relevant sections in Giavarini 2005, pp125-144, Adam 1999, pp164-195, DeLaine 1997, pp131-174, Taylor 2003, pp174-211, and White 1984, pp85-90.

[150] See relevant section on the Roman building industry on Lancaster 2005, pp18-21. The brickwork of the basilica provides for an interesting case study, as it seems to be a material that was able to link most of the Maxentian

largest masonry constructions in ancient history, using a brick and concrete mix to create an 82 x 60-meter foundation, six separate coffered barrel vaults, and a groin-vaulted nave that spanned almost 26 meters. Conservative estimations by the team led by Giavarini suggest that the basilica boasted almost 40,000 m^3 in total material volume, which would mean 11,300 m^2 of bricked surface area, and 850,000 individual bricks (see Figure 12).[151]

Standardized brick production is an interesting case study of the capabilities of Rome's construction infrastructure.[152] Several monuments of the late Empire required hundreds of thousands of bricks, which should have provided an immediate and citywide systemic stress.[153] The sheer amount of bricks needed for construction of the Basilica of Maxentius necessitated the unadulterated appointment of nearly all of the kilns in Latium, the collection of the requisite amount of clay (and the wood to fire it), the organized stockpiling of material at the brickworks or in storage, myriad cartloads dotting the city streets for the entire duration of the work, and the constituent labor to accomplish every task in sequence.[154] The impact on the brick manufacturing industry and the disposition of the periphery of Rome must have been tremendous, as it has been estimated that the project in total would have required 5000 tons of clay and 560 tons of wood to

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constructions together, and could also link the basilica itself to another of the contemporary Tetrarchic building projects, the Curia Julia. The basilica was constructed from *opus latericium*, which resembled the standard brick-faced masonry of the Curia, and may have included elements of the current trend of using *opus vittatum mixtum*, as was used in Maxentius Appian Villa (Coarelli *LTUR* Bas. Max. Entry and Culhed *Conservator Urbis Suae: Studies in the Politics & Propaganda of the Emperor Maxentius*, Uppsala: Paul Astroms, 1994, p58 for speculation on the Appian buildings).

151 Amici in Giavarini 2005, p102.

152 For further studies concerning brick production in Rome, consult Giuliani 1990; Adam 1999, pp 145-150.

153 This figure rightfully posits the Basilica of Maxentius, but also includes aforementioned projects such as the Baths of Diocletian, the Curia remodel, and the Maxentian strengthening of the Aurelian Walls.

154 Also see Homer-Dixon 2006, for specific calculation models of Roman construction and site catchment basin, specifically at the Colosseum. The following calculations for bricks, timber, and other materials are a direct function of said site catchment analysis, as they consider a reverse-engineering of the Basilica's materials and attempt to describe the catchment area required to furnish materials and labor.

fire the bricks.[155] It is useful to note at this point that during the reign of Maxentius, the Aurelian Walls forming a 19-kilometer circuit around Rome were doubled in height using brick-faced concrete. Although there is no evidence for the total amount of bricks needed for the Aurelian Wall project, the staggering figure would likely dwarf that of the Basilica of Maxentius.[156] The thousands of cartloads of bricks for the walls were simultaneously distributed to all exterior ramparts of the city, but were unlikely to interfere with the siphoning of materials to the city center for the basilica. Even so, the millions of bricks demonstrate the infrastructural implications of Maxentian building in Rome, and only begin to demonstrate the logistics involved in the brick-making industry. The entire operation required an intense symbiosis between the various mechanisms of the host city and the palpitating arteries of the material transport process.

The Romans had standardized brick types and implemented brick-stamping as early as the first century C.E. to expedite all imperial construction projects, and located many brickworks in close proximity to the city to provide the most economical building solutions.[157] The emergent mass production of bricks in imperial projects is shown by the sharp increase in kilns in the first

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155 Amici in Giavarini 2005, pp102-103; calculations on wood taken from text, and brick calculation based on a weight of 13 pounds (30x30x5cm bricks on average) multiplied by 850,000 bricks.

156 A preliminary estimate, given that the entire Aurelian Wall was being worked at the same time, must assume 19 kilometers of length, 8 meters of height, and an interior and exterior surface (19,000 meters x 8 meters x 2 sides yields 304,000 m² of surface area). According to Amici in Giavarini 2005, p102, a square meter of wall surface requires 70-80 triangular bricks, which yields a range of 21,280,000-24,320,000 bricks. This figure also does not include the several hundred towers and gates, which most likely garnered more bricks. These figures are of course hypothetical totals for completion of a project that is not completely understood or assigned a specific timeline. Although the brick totals would be accurate for doubling the height of the wall, possible re-use of bricks would admittedly complicate the estimate. As mentioned above, even half of this estimate would be 10,000,000 bricks, or 10 times that required at the Basilica of Maxentius.

157 Adam 1999, pp129-150 suggests that the more rubble-based ashlar masonry work of the 2nd century BCE gave way to a more uniform wall type in *opus reticulatum* by 115 BCE (as evidenced by the Fountain of Juturna in the Roman Forum, the Temple of Magna Mater, and the Temples in the Largo Argentina). However, the still irregular facing type was not codified in manufacturing until after the emergence of *opus vittatum* in the Augustan age. Adam 1999, pp145-146 states that standardized brickwork (*opus testaceum*) was probably introduced in the 1st century CE, and is exemplified by several major projects, including firstly the Tiberian Castra Praetoria built between 21-23 CE.

century, and by the Trajanic era at least 29 kilns were known to be located near Rome.[158] The site catchment basin for Maxentian projects thus included almost the entire periphery of Rome, as the local clay was quarried in the areas of Trastevere, the Vatican, along the Via Salaria, and in the Tiber Valley.[159] As evidenced in Vitruvius' building handbook, Roman brick production technique was guided by a particular attention to the choice and treatment of the clay, and the careful mixing, drying, and firing of bricks.[160] The bricks used in construction at the basilica, mainly *bessales* and *sesquipedales*, went through an arduous but prescribed program of kiln-firing in autumn or winter, and slow even drying during the summer to avoid cracks and imperfections.[161] It has been estimated that a single kiln and its labor teams could possibly prepare 1000 bricks per day from May to September, but the total product was dependent on the quality of clay, the firing process, and the successful drying and covering methods.[162] Vitruvius recommends two years to sufficiently dry bricks for use in construction projects.[163] This postponement was significant enough to affect the scheduling for any large-scale project, as bricks ordered directly by Maxentius would likely not arrive on site until the second year of construction. In order for a newly-ascended Maxentius to immediately begin work at the Basilica, he must have had custody of a sizeable amount of readied bricks, possibly left over from the Diocletianic projects. Regardless of order date or kiln provenance, several hundred cartloads of bricks per day were funneled through the under-construction Aurelian Walls towards the forum. These carts populated the same infrastructural arteries as several other locally-sourced

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[158] Amici in Giavarini 2005, p103; this figure is up from only 9 kilns in the Flavian era only 10 years prior.

[159] Amici in Giavarini 2005, p101.

[160] Vitruvius *De. Arch*. 2.8.18-19.

[161] Adam 1999, pp62-65 and Amici in Giavarini 2005, pp96-103.

[162] Amici in Giavarini 2005, p103.

[163] Vitruvius *De. Arch*. 2.8.18-19.

concrete ingredients, and this common daily circumstance defined the symbiotic mutualism inherent in the entire system.

The technique of Roman concrete (*opus caementicium*) is defined by the mixture of a binding element with an aggregate, and in the case of hydraulic cement, setting it with water.[164] The Romans developed an incredibly strong binding mortar, which relied on constituent elements of lime (*calx*) originating in the hills southeast of Rome, and *pozzolana* quarried in the volcanoes of the nearby Alban hills. This combination mixed with an aggregate like bricks, tufa, or pumice, created the *caementum*, which was employed on its own for foundations and

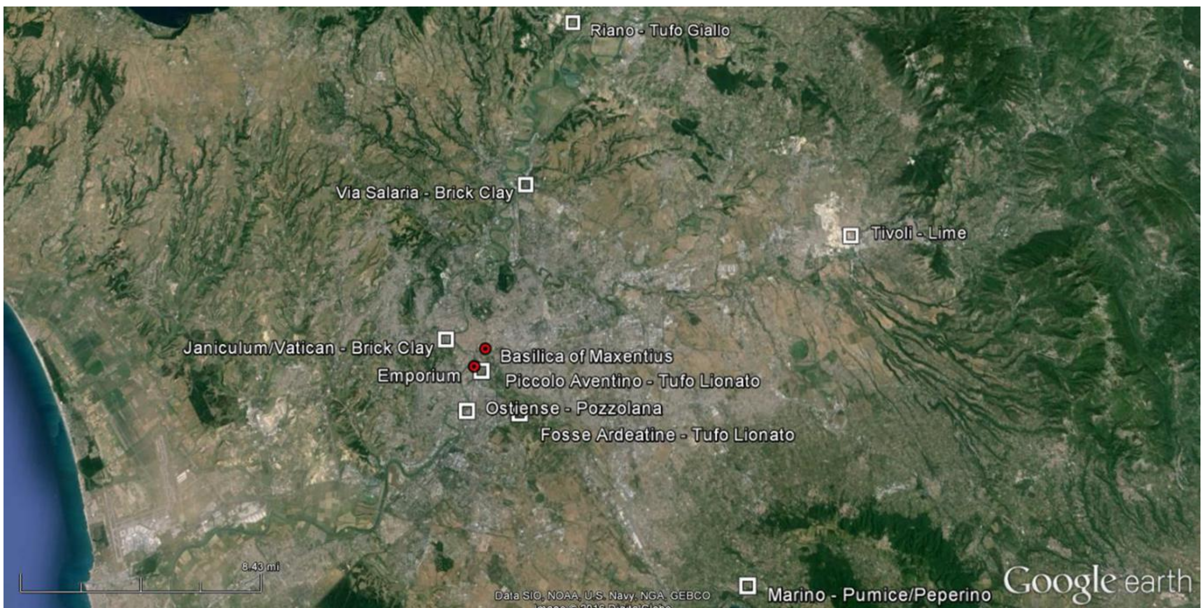

Figure 13: GoogleEarth satellite view of greater Latium, depicting the site catchment basin for the brick-and-concrete construction elements of the Basilica of Maxentius. Map data: Google, DigitalGlobe.

164 DeLaine 1997, p85; Adam 1999, pp177-191; Adam creates a discussion of concrete construction, which is supplemented by Lancaster 2005, pp22-48 on general concrete use, and Taylor 2003, pp195-211 on concrete use at the Pantheon. Also see the small volume Porter *What Rome Was Built With: A Description of the Stones Employed in Ancient Times For Its Building and Decoration*, London: Henry Frowde, 1907.

vaulting.[165] The technique of *opus caementicium* was then demonstrated in the walls and piers of the basilica by setting the *caementum* mixture between two brick facing walls. This technique was painstakingly perfected by the Romans over the centuries, and the materials and labor were largely centralized by the 4th century.[166] The site catchment area for Roman concrete is defined by the specific elements required, and in the late Empire was comparatively small and confined to the nearby periphery of Rome (see Figure 13).[167]

The aggregate for *caementum* was for the most part sourced in Latium, defined by the aforementioned discussion of brick clay quarried either in the Janiculum/Vatican area or in the northeast Tiber Valley, and fired in kilns to the south.[168] Tuff (or tufa/tufo) is one of the more abundant and widely-used materials in Roman construction, and *tufo lionato* suitable for concrete assembly was sourced from several locations convenient to Rome, including locations as near as the Piccolo Aventino near San Saba and the Fosse Ardeatine only one kilometer distant.[169] The Basilica also used *tufo giallo della via Tiberina*, which was sourced just north of the city along the banks of the Tiber near Riano.[170] Pumice was also used as aggregate in

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165 DeLaine 1997, p85, Amici in Giavarini 2005, p112.

166 Amici in Giavarini 2005, p112; *opus caementicium* technique was termed "the most profound influence of Roman engineering on the modern world." Dynamic concrete construction allowed for the expedited manufacture of the Basilica and the successful employment of the Roman construction network to stage a massive project in a tightly-confined space. The structure of the Basilica of Maxentius was based on brick and concrete rather than marble, although it featured marble columns, floors, and revetments throughout. This practice was also common in its forum counterparts, the Basilica Aemilia and Basilica Julia, although these Basilicas featured more traditional basilica naves without vaulting. Specifically, these basilicas were built (and re-built) with marble columns and timber roofing, and are discussed in a relevant section in Boethius 1994, pp149-156.

167 The catchment in the late Empire is confined to the periphery of Rome if the builders indeed used *pozzolana* from the nearby Alban Hills, and not the Bay of Naples, which will be discussed below.

168 DeLaine 1997, p87. Concrete vaulted construction includes many brick and terra cotta forms, including those used for facing concrete walls, lining the vaults, as the floors and *pilae* supports, and as rectangular *tubuli* for heating the walls, and amphorae pots for inner vault support.

169 Ibid; also Ventriglia *Geologia del Territorio del Comune di Roma*, Rome: Amministrazione Provinciale di Roma, 2002, p208, and Lanciani *The Ruins and Excavations of Ancient Rome*, Boston: Houghton Mifflin, 1897, pp32-33.

170 Lancaster 2005, pp63-64, Coccia and Fabiani "Le indagini archeologiche recenti," in Giavarini ed. *La Basilica di Massenzio: ricerca interdisciplinare applicate allo studio e alla conservazione di un monument*, Roma:CISTeC,

lightweight vault construction from the time of the Republic, and was most likely sourced near the peperino quarries at Marino, although Blake has noted specific deposits on the Velian Hill near the site of the Basilica of Maxentius.[171]

The *caementum* at use in the basilica relied on many of the volcanic materials which could be found in the surrounding hillsides, and some of the best-known quarries include the volcanic flows that penetrate from the Alban Hills all the way to the base of the famous Tomb of Caecilia Metella on the Via Appia.[172] The key ingredient added by the Romans to increase the binding strength of concrete was volcanic *pozzolana*, generalized as *'pulvis puteolanus'* after the significant deposits of volcanic dust collected near Puteoli in Campania.[173] Lancaster mentions that although the Campanian *pozzolana* was exceedingly efficient in underwater construction, Imperial-era builders used local Roman *pozzolana* almost exclusively, as opposed to importing the material from further south.[174] This decision explicitly takes into consideration the Theory of Constraints, and also reaffirms the fluidity of a living symbiotic system. The *pozzolana rossa* that was used at the Basilica of Maxentius was thought to have come from the eastern part of city

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2003: p38 and Figure 8, Amici in Giavarini 2005, pp109-114, Jackson et al. "Geological Basis of Vitruvius's Empirical Observations of Material Characteristics of Rock Utilized in Roman Masonry," in Dunkeld 2006: pp1689-1690 and Figure 3A. *Tufo giallo dell via Tiberina* reappeared at the Basilica of Maxentius after being absent in constructions since the mid-2nd century, according to Lancaster.

[171] Ibid; also Blake 147, p41; for use of pumice in the Republic, see Amici *Foro di Traiano: Basilica Ulpia e biblioteche*, Rome: Comune di Roma, 1991, pp52-55, 162. Blake also notes pumice sources at the Janiculum Hill, which is also relatively convenient to Rome's center. I am assuming that the Velian Hill deposit must have been used up by the time of the Late Empire, unless it was quarried during the building of the Basilica of Maxentius, which was unlikely judging by the density of other buildings in the area. DeLaine and others provide the assumption that the pumice used in concrete aggregate at the late Imperial project the Baths of Caracalla may have come from Marino, not Rome.

[172] DeLaine 1997, p85; also Blake 1947 and Ventriglia 2002.

[173] Lancaster 2005, p54.

[174] Lancaster 2005, pp54-58; builders either called this by its general name of '*harena fossica*' (pit sand), or by the specific types *pozzolana rossa, pozzolana nera, or pozzolanella*.

along the Via Ostiense, possibly near the medieval church of San Paolo fuori le Mura.[175] The building projects of Maxentius were known to have used *pozzolana* with red granules of up to a centimeter in diameter, and modern laboratory tests to recreate mortar have relied on Vitruvian prescriptions to estimate the proportion of *pozzolana* with respect to lime and water.[176] Although revolutionary for its contribution to the compressive strength of mortar, *pozzolana* did not significantly stress the construction infrastructure of Rome.[177] The substance was found just outside the Aurelian Walls, and comparatively easy to transport considering its sand-like character. Of the two component materials of *caementum* mortar, lime was far more difficult to procure, transport, and work.

The sources of stone burnt to create lime are plentiful, but difficult to assign to specific projects, considering that lime is consequently only found as a component of already-mortared architectural monuments. Several ancient sources record a variety of materials that were used, including mostly *album saxum* (limestone), travertine, river stone, *rubrum*, *spongia*, and marble.[178] It has been surmised that the most likely source of lime for late Imperial projects are the limestones from the lower ring of Apennine Mountains bordering Campania, the travertine quarries in Tivoli, and the seaside slopes near Terracina.[179] The locations at Terracina and Tivoli

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[175] DeLaine 1997, pp85-86; based on an analysis of the *pozzolana* composition types used at the Baths of Caracalla. Amici in Giavarini 2005, p109-110 suggests a similar *pozzolana* composition at the Basilica of Maxentius. Also cf. Blake 1947, p44, Lugli *La tecnica edilizia romana* 2 vols, Rome: Bardi, 1957, pp400-401, Ventriglia 2002, pp28-30.

[176] Lancaster 2005, p57, Vitruvius *De. arch*. 5.12.8-9, Giavarini 2005, p110-111. Tests carried out by A. Samuelli Ferretti concluded that best success was achieved with 1.0 parts lime, 3.0 parts *pozzolana*, and 1.4 parts water in volume.

[177] Adam 1999, p74 for the addition of pozzolana to Roman mortar. Also consult Pliny *Natural History* 35.166 for the marvel that is Roman *pozzolana*, and its use in architecture.

[178] List compiled by DeLaine 1997, p88; included are Vitruvius *De. Arch*. 2.5.1, Cato *Agr*. 38.2, Pliny *Natural History* 36.53, Faventinus 9, Palladius 1.10.

[179] DeLaine 1997, p88 and Lugli 1957, pp393-394. Symmachus *Relat.* 40 and *Cod. Theod*. 14.6.4 explicitly mention that lime for repairing city walls and ports were taken from the locations near Terracina.

would be most suited to water transport, which would benefit the cost and energy levels required to bring the stones to Rome.[180]

Regardless of provenance, all stones were then fired in kilns to produce quicklime, which was the essential byproduct required for concrete mortar. It is unknown whether the lime kilns were preferred nearer to the quarries, ports, or the construction site, but evidence from Ostia and Rome itself indicates that the volatility of the materials necessitated strict planning for successful use. Quicklime then required the second step of slaking to produce a suitable material to mix with *pozzolana* and water for *opus caementicium*.[181] Unslaked lime was very unstable, and if care was not taken to keep it clear of carbon dioxide and moisture of the air ("air-slaking"), it would be rendered inert and unusable.[182] Lancaster admits the possibilities of a warehouse system for receiving and transporting slaked and un-slaked lime, which would assure proper treatment of the raw materials of construction.[183] These exacting steps of the process necessitate dynamic planning and a suitable infrastructure network to assure that the binding agents are strong enough to support the concrete-vaulted halls of the basilica. The cautious processes of lime production and transport led to its eventual arrival on site, where it would be mixed with *pozzolana*, water, and aggregate to form the *caementum* needed for the most basic of construction tasks, including foundations and walls.[184]

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[180] DeLaine1997, pp88-89 mentions that all products from the travertine quarries near Tivoli would have used the Anio tributary to deliver stones to Rome. Terracina, as noted, lies on the seaside, and would have been ideally situated to transport stones up the coast and down the Tiber to Rome. Indeed, an *exonerator calcarius CIL* VI 9384 is recorded in Rome, and the resulting *collegium* may have been involved in unloading limes from river boats.

[181] Adam 1999, p65; Adam provides an overview of the overall process of firing and slaking lime on pp65-76.

[182] Lancaster 2005, p54.

[183] Ibid; Lancaster notes that the high quality of lime used in building construction "suggests that there existed a developed supply network to ensure the best quality." Even Alberti in *De Re Aedificatoria* later suggested that un-slaked lime should not be allowed to lie around for too long after firing, or it would become useless.

[184] The logistics of mixing the lime, *pozzolana*, water, and aggregate together is severely problematic in itself, as the workmen would likely employ gigantic vats for the mixing and rely on a ready water supply as well. This problem is addressed more thoroughly in Chapter 4 concerning the worksite.

In order to successfully construct the soaring vaults of the basilica, the architects and foremen necessarily leaned on the vital infrastructure of the timber industry, as the centering, formwork, shuttering, and even construction implements like cranes and lift towers required massive amounts of wood. Although the basilica required no roofing or support beams, timbers of varying size and shape were conspicuous in almost every single phase of the project. Engineers and carpenters employed timbers to create the vast web of centering under the vaults, architects specified material manipulating machines that relied on strong wooden beams, and site laborers required basic wooden structures to bolster masonry walls. Even shipbuilders, kiln workers, quarrymen, and other smiths relied heavily on a resilient supply of wood. There is a dearth of archaeological and literary evidence for the amount, size, and character of wooden timbers explicitly employed on architectural projects, but the timber industry in itself is well attested.

Sources such as Vitruvius, Pliny, and Columella among others address the sources of suitable timbers, and provide an idea of the size and scale of the antique woodworking industry.[185] Romans seemed to be particularly fond of fir timber, as the common European fir of peninsular Italy was known to be highly prized by woodworkers and shipwrights for its height and straightness.[186] Firs could be found the length of the Italian peninsula, and sources from the Roman Republic record the relatively easy transport of firs from the mountains of Etruria and Umbria down the Tiber.[187] Only the larch tree was known to have produced longer timbers than

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[185] Vitruvius and Pliny discussed in following; also see Columella *De Arboribus* 1.1; Cato *Rust.* 1.6.19; Juvenal 3.254-3.256; Seneca *Ep*. 90.9.

[186] Ulrich *Roman Woodworking*, New Haven: Yale University Press, 2007, pp242-243. Also see Meiggs *Trees and Timber in the Ancient Mediterranean World*, Oxford: Oxford University Press, 1983.

[187] Mature firs reached up to 45m (147 feet) high, which makes them the tallest and straightest of the native Italian trees. Livy 28.45.18 describes the preparations made for war against Carthage in 205 BCE, revealing the essential role fir trees played in the construction of the Roman fleet. Ulrich 2007, p250 cites a 1999 study by Fioravanti and

fir, and Pliny records a famous episode where a 120-foot-long beam was brought back from the Alpine province of Raetia by Tiberius, where it was exhibited for decades on a Roman bridge until being employed in building construction by Nero.[188] Although shipping Larchwood from the Alps was undoubtedly an enormous undertaking, Pliny records the harvesting and transporting of several timbers directly to Rome, as it utilized the Adige and Po Rivers and the Adriatic Sea.[189] The majesty of large timbers procurement indicates the capacity for spectacle within the city, but the reality of most construction only dictates a large volume of wood, not a particular cut.

Several areas of the Apennine foothills provided centuries of Roman logging, and Ulrich suggests that the pine and fir forests within a 60 kilometer radius from Rome were probably logged from an early date and never depleted.[190] Pliny and Strabo suggest that the area for miles around the Tiber River were harvested for timber, and that during the winter the Tiber was navigable to logging traffic for 150 miles.[191] Wood culled for specific construction purposes like centering, formwork, scaffolding, or ladders was most likely shipped down the Tiber and

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Caramiello which records that silver fir was found in 60% of the 200 wood samples analyzed from the sites of Pompeii and Herculaneum.

[188] Pliny *Natural History* 16.200; "what is considered the largest tree ever seen at Rome down to the present time was that marvel Tiberius Caesar exhibited on the bridge where the mock naval battles are held. It had been imported to Rome with the rest of the timber, and it lasted until [it was employed for] the amphitheater of the emperor Nero. It was a beam of larch, 120 feet long and of a constant thickness of 2 feet, from which could be surmised the almost incredible height of the rest [of the tree] by estimating its length to the top." Vitruvius *De. Arch*. 2.9.14 wished that all buildings in Rome could have been constructed with larch, because of its reputation of strength and fire resistance.

[189] Pliny *Natural History* 16.195-200.

[190] Ulrich 2007, pp264-5; however, Ulrich mentions that the surrounding land is very rugged, and it might have been practical to look for more distant sources with fewer obstacles to transport. The Alba Longa tree stand was closest to Rome along the Via Appia, but it may have been forbidden for its sacrosanct status to Diana, Jupiter Latiaris, and Mars, according to Pliny.

[191] Pliny *Epist.* 5.6.12; Strabo 5.2.5.

offloaded at the Emporium for drying and seasoning.[192] Other common wood for firing kilns and similar tasks was probably transported in smaller volumes on land to the estates where they were needed. In all, the logging industry was able to function continuously along multiple infrastructural lines throughout the entire construction process. Depending on the demands of the work site, even massive imported timbers may have been necessary and furnished from far-flung locations.[193] DeLaine submits that there is no way to know the extent to which construction projects employed large and expensive timbers, but alludes to a need for wooden beams to routinely span at least 30 meters clear in *thermae*-style projects.[194] Larger beams would involve a vast degree of planning, specifically when considering the time and cost of felling, harvesting, shipping, loading, drying, and transporting timbers of size and weight equivalent to marble monoliths. Stone columns and wooden beams of incredible size would employ the already discussed overseas trade infrastructure to arrive in the supply yards, but the completion of their journey relied heavily on overland hauling systems, the viability of Roman street transportation, and the successful symbiosis between material and support avenue.[195]

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[192] Ulrich 2007, p261 mentioned that air-drying "was and is still the preferred method of seasoning wood. Practical craftsmen knew that stacking wood in a warm place would accelerate the process." Pliny *Natural History* 13.99 is the only source that illuminates the process of drying wood by burying it in piles of grain or earth, where the dried grain can apparently wick the moisture and a controlled and steady rate. Columella *Rust.* 1.6.19 advised that "green wood could be stacked in the smoke room of a farm for curing, utilizing the heat (not the smoke) for value." Palladius 12.5.3 and Cato *Rust.* 31.1 suggest that Italians sometimes buried their timber in sand by the sea for a year to season it, although Hanson "The Organization of Roman Military Timber Supply," *Britannia* 9 (1978): 293-305, p296 suggests that this kind of treatment of wood should be associated with shipbuilding activities.

[193] Ulrich 2007, p150 suggests that "by the period of the late empire, the largest trees accessible to loggers likely had been harnessed for shipbuilding and large construction projects." The Basilica of Maxentius may have been a large enough project to take advantage of large timbers. According to the Price Edict of 301 CE, there were fir and pine timbers in Rome 75 feet long and 6 feet in girth. Longer timbers undoubtedly existed though, because of archaeological evidence of 80-foot spans in Early Christian basilicas.

[194] DeLaine 1997, pp91-93; DeLaine stipulates 30 meter poles for standards at the Baths of Caracalla, and 25 meter spans for the major timbers at the frigidarium.

[195] In addition to larger timbers that were special ordered for structural supports, the plethora of smaller timbers for scaffolding and site support were likely stored and reused for many projects. As mentioned above, the largest mass-storage yard was the Emporium, and perhaps the Porticus Aemilia provided a covered solution to keep rain and the elements from damaging or warping the wood supply. For Maxentian projects, the timbers may have been spot-

2.8. Land transport mechanisms and the streets of Rome

When considering the entirety of construction traffic infrastructure, the logistical ease and cost effectiveness of overseas transport is trumped only by the obvious necessity to convey each material from the port to the building site over land. Imperial Rome provided the benefit of paved streets to run materials to the site, but centuries of organic urban growth prevented the reliance on a straightforward grid. Construction planners undoubtedly used the straightest, widest, and most appropriately sloped roads for the largest building materials, but even these broad thoroughfares tightened up considerably when approaching the city center. Transporting loads outside of the city walls would be much easier than entering the city and subjecting construction resources to the density created by additional pedestrian and commercial traffic. Nevertheless, all materials needed to be successfully moved from the periphery to the center, whether it be locally-sourced materials through the various Aurelian Wall gates, or imported materials centrally stored at the Emporium district in the extreme southwest of Rome.[196] Regardless of load type, Romans

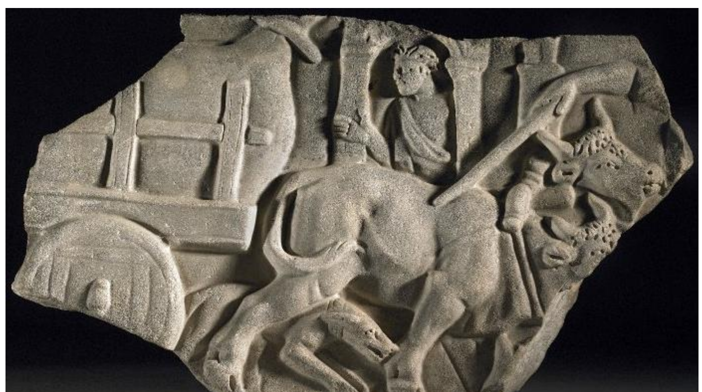

Figure 14: Plaustrum, Roman method of transport by chariot, oxen, and neck yoke (3rd c. CE). British Museums, London. Inv. 1805,0703.458.

stored on site in order to reuse for centering and formwork at the Basilica, and also the Temple of Venus and Rome and the smaller Temple of Romulus.

[196] Also noted by DeLaine 1997, pp98-99. Although most of the materials for construction were brought from the periphery to the center, there was undoubtedly much construction material that was unused, damaged, or served its purpose, and needed to be brought away from the site and disposed of or reused. Some of this material must have been brought back to the storage yards, but additional debris also needed disposal. A famous example of such disposal of terra cotta pottery shards is the build-up at Monte Testaccio in Rome (near the Emporium). Possibly this area could have been used for similar disposal of construction debris or damaged materials as well. In any case, cartloads full of materials destined for the worksite passed by an equal amount of cartloads headed back to the yards to refill.

preferred that land transport be conducted by cart, excepting for cases where materials could be broken up into smaller units and carried by pack animal and cases where larger materials would need special consideration.[197]

Most material loads were conveyed by carts or wagons towed by donkeys, mules, horses, or oxen (see Figure 14). Ox-cart was by far the most common, owing to both the capacity of oxen to be relatively sure-footed and reliably laden with extremely heavy loads.[198] Whereas the smaller pack animals were capable of carrying only 55-135 kilogram, a single laden ox could manage between 400-640 kilograms.[199] Every 2-3 animals employed for conveyance required at least one drover to manage them, and multiple yokes necessarily resulted in a gain in weight capacity and a loss in energy efficiency.[200] The rate of travel of laden pack animals has been estimated at about 1.67 kilometers per hour, and this is certainly considering a straight pathway with well-built carts and diligent drovers.[201] Although the two-axle *plaustrum*-type cart pulled by oxen have been documented by several sources from the Greek and Roman world, specific load capacities seem to be relegated to each individual case.[202] Large construction materials like

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[197] Ibid; also Landels 1978, pp170-185; White 1984, pp127-140; Cotterell and Kamminga *Mechanics of pre-Industrial technology*, Cambridge: Cambridge University Press, 1990, pp193-264; Burford "Heavy transport in classical antiquity," *Economic History Review* 13 (1960): 1-18; Bernard "The Transport of Heavy Loads in Antiquity," in Marcks-Jacobs and Seiler eds. *Perspektiven der Spolienforschung* 1, Berlin: De Gruyter, 2013: 99-122.

[198] DeLaine 1997, p98.

[199] These numbers are according to the *Cod. Theod.* 8.5.30 which cites 1500 librae (500kg), the *Price Edict* 17.3, 14.8 which cites 1200 librae (400 kg), and Xenophon *Cyr.* 6.1.52, which cites 25 talents (640 kg).

[200] DeLaine 1997, p108; this includes an estimate from Xenophon that over 8 yokes together are able to carry only 15 talents (380 kg) per yoke, as opposed to his earlier estimate of 25 talents for a single ox. Meiggs 1983, p340 also estimates 340 kg loads for each yoke over 9 yoke total. The assumption of one drover for each pair of oxen is given in several ancient and modern sources, including Tomassetti "La Campagna romana: antica, medioevale e moderna I," in Chiumenti and Bilancia eds. *La Campagna romana in genere, Arte e archaeologia, studi e documenti 12*, Naples: Banco di Napoli, 1979, p102, 278.

[201] DeLaine 1997, p98, 108. When the oxen pairs are multiplied, the material trains can get exponentially larger and more intrusive. This circumstance will be addressed in Chapter 3 on the spectacle of transport through the city.

[202] Varro *Ling.* 5.31 for timbers and stone; *Dig.* 9.2.27.33 Ulpian for heavy stone; *Dig*. 9.2.52.2 Alfenus for heavy loads; Juvenal 3.254-56 for large timbers. Bernard 2013, p107 and Burford 1960, pp11-12 mention the dearth of

marble monoliths and timbers necessitated specialized carts with amplified load-bearing capacities.[203] Bernard mentions a large 18-wheeled wagon at use in Egypt's Mons Claudianus quarry, but this type of vehicle was probably an anomaly, and its use admitted by large open tracts of road and not at all suited for Rome's city streets.[204]

The most tangible coincidence of each material supply network mutually sharing the intact infrastructure of Rome is the contact of oxen hooves and wagon wheels with the surface of the street.[205] Each cartload of materials had to run at least two wheels over the paved streets of Rome, and the continual stability of loads were at the whim of wheel construction and proper balanced axles. Cart wheels were built by Roman wheelwrights, who had the uncanny ability to identify sturdy wooden planks from standing timber,

Figure 15: Mosaic detail showing wheeled transport by oxen-pulled cart. Mosaic from Piazza Armerina, located in the Grande Caccia corridor (320-350 CE). Photo by author.

evidence for specific loads carried, and in which scenario. Bernard cites the *Cod. Theod.* 8.5.28 for the *angaria* cart type being legally able to carry about ½ ton, but as large stone blocks were significantly large than this, exceptions must have been made.

203 Burford 1960, p12 notes that abnormal loads dictated by building specifications "must have required special roads and waggons." Also, a so-called "little cart" has been described for use at Greek quarries in 327 BCE by *IG* 2 1673.11-43 and Herodotus *Mechanics* 3.1.

204 Bernard 2013, p107; citing discoveries by Peacock/Maxfield 1997 and Bulow-Jacobsen 2007. Vitruvius *De. Arch*. 10.2.11-12 also describes the special frame built by Chersiphron for heavy transport at the Temple of Diana in Ephesus, where the architect had no confidence in two-wheeled wagons to transport the column drums.

205 Also notable of the impact of oxen on the city streets is the amount of excrement produced, and the necessity to deal with it. An interesting paper recently presented on this topic is Triantafillou "Beasts of Burden: Animal Power for Public Construction in Rome," paper presented at the Archaeological Institute of America 117th Annual Meeting, San Francisco, CA, January 2016, in which the author specifically addressed the need to deal with the excrement from beasts of burden during construction material transport.

and secured the durability of wheels by air-drying planks for five years or longer.[206] Depictions of wheels at the 'Great Hunt' mosaic of Piazza Armerina shows both planked and solid-disc varieties, with the possibility of iron 'tires' around the edges (see Figure 15).[207] The sound of these metal tires clattering along the roadways has been sufficiently documented by Roman sources, as wheeled traffic was not only a frequent occurrence during times of great building, but also during everyday conveyance.[208] Wheeled construction traffic was undoubtedly aided by the street network itself, as Roman roads were usually complete with ruts cut into the paving stones to provide a means of steadying and directing the wheels.[209] The Romans were even specifically noted by Poehler as preferring to drive their carts on the right side of the street, which further strengthens the assertion that everyday wheeled traffic needed to be strictly arranged and guided in the central city.[210] In the later empire, the state took steps to safeguard the overall contextual topography of the city from dangerous construction loads, and penalties were enacted on builders for exceeding weight limits with massive carts.[211] Larger construction materials also employed

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[206] Ulrich 2007, p202.

[207] Ulrich 2007, p206-207; this depiction is specific to the Maxentian era (300 CE), and depicts wheels with rims, spokes, and a hub. The wheels are designed "so that the stresses of the carried weight and the contact with the road are best absorbed by the fibers of the wood employed." Wheel dynamics allow the weight of the cart to hang from and be carried by the spokes.

[208] Roman wheeled traffic for construction noted by Tibullus *Vita Tibulli* 2.3.43-44, Seneca *Ep.*56, Martial *De Spect*. 5.22, and Juvenal *Satires* 3.254-3.261. Other references for wheeled traffic in Rome given by Statius *Silv.* 4.3.20-55, Varro *On the Latin Language* 5.31, Cicero *Against Verres* 2.5.11.27, *Historia Augusta, Pertinax* 8.6-7, Pliny *Natural History* 7.84.

[209] Road ruts are introduced in Humphrey et al. 1998, p418 "10.15 Road Ruts." Track or ruts also alluded to in DeLaine 1997, p98, and White 1984, pp136-7. Ancient Romans would sometimes refer to these road ruts in their literature, which attests to their commonality in the streets. In literary record, the road ruts are even metaphorically referred to as moralistic rules, as in the colloquialism "stay the course." These sources include Quintilian *On the Training of an Orator* 2.13.16, Juvenal *Satires* 14.33-37, and Nicander *Theriaca* 367-371.

[210] Poehler 2003, pp7-15.

[211] *Cod. Theod.* 8.5.17.

additional mechanisms like sleds and pulleys to steady loads down streets and guide them around corners.[212]

The intricacy of conducting such large materials along the two kilometer route from the Emporium supply yards to the Basilica of Maxentius made planning difficult. The unending train of small material supply carts complicated the street infrastructure during construction, and large materials needed a specific directed course to assure success in delivery. The urban topography

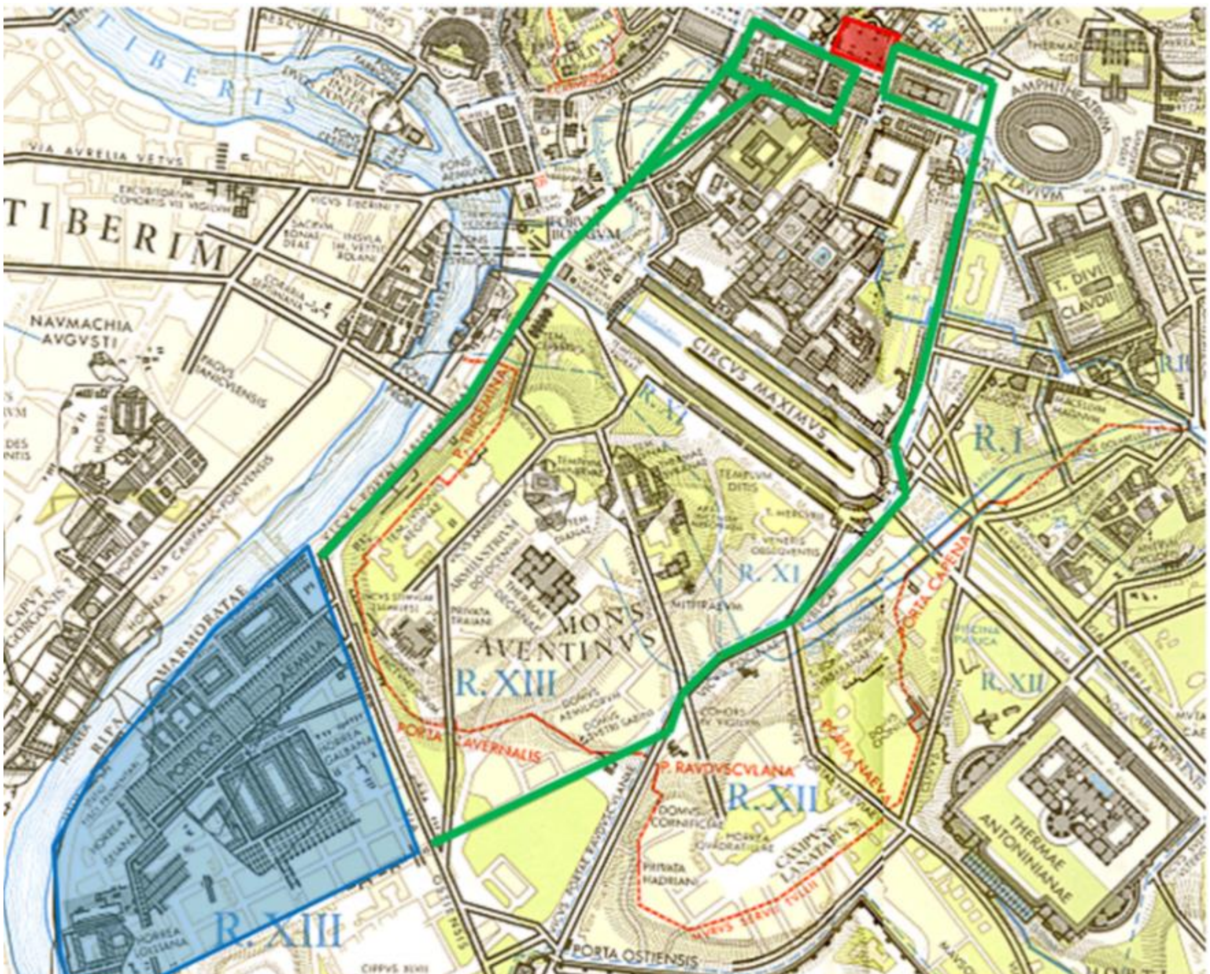

Figure 16: Southern quadrant of Imperial Rome. Red indicates Basilica of Maxentius. Blue indicates the Emporium marble yards. Green indicates the two possible routes pursued from storage yards to worksite. Map credit: Scagnetti *Roma Urbs Imperatorum Aetate*, Rome: Staderini S.p.A., 1979.

[212] Adam 1999, pp27-29, Bernard 2013, p108, Fitchen 1986, pp169-178.

at both the northern and southern end of the city center was extremely dense, and yielded only a few suitable avenues.[213] The route to the northern end of the forum probably followed the Tiber to the Forum Boarium and the Via Aurelia, while the route towards Maxentius' construction was probably down the Via Ostiensis past the Colosseum valley (see Figure 16).[214] Either route would have been extremely slow and difficult, considering both the possible late-Imperial degradation of Roman streets and the aforementioned sluggish speed of laden oxen.[215]

The requirements of transferring the basilica's largest unwieldy building material, its Proconnesian marble columns, may have required a train of oxcarts hundreds of feet long and difficult to maneuver.[216] For this conveyance, the streets of Rome were cleared and wide paths opened up. Oxen and drovers were hired, carts, pulleys, logs, and lifting apparatus were arranged, and workers continuously readied the route.[217] At this crucial point in the construction process, all of the material supply infrastructures were likely employed to their capacity. Nearly every material that defined the total site catchment area for the Basilica of Maxentius had now made its way into the city. The continuous stream of bricks, mortar, marble, and timber was a

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[213] Based on the vector from the Emporium marble yards to the building site, several of the hills of Rome would be directly in the way, and the route would move north or south around the Palatine Hill; even if there was another marble yard in the Campus Martius (an idea which Maischberger discounts in "Some Remarks on the Topography and history of imperial Rome's marble imports," pp325-334), the route from the Emporium district would still appear to be easier to traverse than moving through the area of central Rome to the Forum. Routes based on an analysis of the city of Rome in the form of the map *Roma Urbs Imperatorum Aetate* (by Fransiscus Scagnetti in 1979).

[214] This conclusion is specifically derived from the archaeologically-known pathways through Rome, also taken from the Scagnetti map.

[215] DeLaine 1997, p98, citing Burford 1960 in which heavily-laden oxcarts are estimated to travel approximately 1.67 kilometers per hour; see also Poehler 2003 on worn-down Roman pavement, which is the basis for his study.

[216] The size of the columns has been listed at 1.82 meters at the base and rising 15.72 meters, which gives a total volume of 40.8 square meters; if estimating the weight of marble at approximately 160 lb per square foot (2.82 tons per cubic meter), it yields 115.26 tons. Calculations and further explanation of this particular oxen train will be carried out in the next chapter.

[217] The character of the workforce would be composed of drovers needed for each pair of oxen, foremen needed to supervise the entire operation (provided by marble yards or imperial design staff), workmen to steady loads as they are transported, and miscellaneous workmen to clear areas ahead and behind; in total the workers might number in the hundreds.

living embodiment of the requirements of large-scale Roman building. In defining both the physical and intangible boundaries of the Basilica's catchment basin, I have speculated on the perceived difficulties of organizing such a widespread system. The labor management network deployed by the Romans is a way to seamlessly link the idea of an overarching catchment with the quantifiable energy required to build. Architectural energetics analysis thus considers the numbers put forward by a site catchment inquiry, and hypothesizes the total workforce needed to fulfill each specialized task on site and abroad. These two methodologies together can generate a succinct model for the process of Roman construction, and the next step is to observe and evaluate the symbiotic system at work. At this stage, the various infrastructures of large-scale construction had served their purpose, and the vast spectacle of Roman building would soon provide confirmation of successful symbiosis between the associated construction processes and the city.

3. Building Begins: Materials Maneuvering the City and the Spectacle of Construction

3.1. The imaging of antique spectacle and representations of the construction process

There was no mistaking the cacophony created by heavy material transport in the Roman city, as recorded by Tibullus concerning a merchant in the Augustan age,

> "His fancy turns to foreign marbles, and through the trembling city his column is carried by one thousand sturdy pairs of oxen."[218]

The transport and subsequent physical manifestation of materials at the building site serves as the ultimate proof of the successful symbiosis of the construction process element in its urban context. Although extant archaeological remains can make the amount and size of all building materials a mathematically-derived conclusion, the manner in which construction progresses is more difficult to assume. In order to conclusively recreate the Roman construction process, this study relies on first-hand accounts of engineering technique and material-working technologies, and in certain cases, representational imagery of construction sites. Specific types of imagery definitively reveal that construction was witnessed and legibly recorded, which may indicate that construction was watched and experienced as spectacle. The process of construction exerts such a pressure on the urban environment that it floods the streets with materials, workmen, and implements, thus creating an irresistible pull for the interested onlookers. The "spectacular" here is consequently submitted as the visible slippage of a series of overarching symbiotic relationships between the processes and the city.

Indeed, certain events inherent to large-scale building construction provided the opportunity for a vast spectacle in Rome. The steadfast recording of initial building vows,

[218] Tibullus *Vita Tibulli* 2.3.43-44. Also, In Seneca *Epistulae* 56, the author notes the great noise from a simple passing carriage; the noises from the many carriages rumbling along these routes would undoubtedly have the power to rouse anyone in the near vicinity, and this noise might have trumped the normal construction noises from the Forum as well.

groundbreaking ceremonies, and commemorative dedications indicate that the Roman people were interested in acknowledging several junctures of the construction process. Massive allocated resources like Larchwood timbers and colossal stone blocks have merited specific mention in historic accounts, and the consistent and ordered delivery of these materials to the site can even resemble a characteristic Roman procession.[219] Gargantuan raw materials have a sustained history of being heartily celebrated on their arrival to construction sites, ranging from Roman models to contemporary examples. Romans specifically took pride in parading monoliths, as evidenced by the Augustan-era carting and shipping of stone obelisks thousands of miles from Egypt to the capital.[220] The arrival in Rome was met by incredible fanfare, as these architectural objects served as prescient reminders of the breadth and power of empire. A grand entrance to Rome was notoriously worthy of spectacle, whether the subject was man or material. Late Imperial panegyrics frequently commemorated *adventus* processions of visiting emperors through the city, and a particular example from 291 CE references the visiting emperor, the fanfare, and even the architectural environment created for the spectacle. [221]

[219] Pliny *Natural History* 16.200 specifically mentions the largest beam of larchwood ever brought to Rome. Large obelisks have been mentioned in accounts ranging from Marcellinus to the Historia Augusta. Several famous stones were cut during the Roman period in the quarries of Baalbek; the famous *Hajar al-Hibla* (or "The Stone of the Pregnant Woman") had been supposed by the *Deutsches Archäologisches Institut* in 2014 as the largest stone ever cut by men. Several massive blocks have also been noted in the Roman quarries near the Temple of Jupiter sanctuary, including the *Hajar al-Hobla* (or "The Stone of South"). At 1242 tons, the *Hajar al-Hobla* may be even larger and heavier than the *Hajar al-Hibla*. See Ruprechtsberger "Vom Steinbruch zum Jupitertempel von Heliopolis/Baalbek (Libanon)," *Linzer Archäologische Forschungen* 30 (1999): 7–56; Adam, "À propos du trilithon de Baalbek: Le transport et la mise en oeuvre des megaliths," *Syria* 54, no.1 (1977): 31–63.

[220] See Swetnam-Burland *Egypt in Italy: Visions of Egypt in Roman Imperial Culture*, Cambridge: Cambridge University Press, 2015; pp28-40, 68, 90-96. Also, see discussion of "East versus West" and the image of urban Rome created by Augustus in Favro 1996, pp98-103.

[221] *Pan. Lat*. 11(3).11.1-4, "what a spectacle your piety created…when you passed through the door and rode together through the middle of the city, the very buildings, I hear, almost moved themselves, when every man, woman, tiny child and aged person either ran through the doors into the open or hung out of the upper thresholds of the houses." Late Imperial political figures were intently interested in the *adventus* procession and the architectural space built to take advantage of the grand imperial ceremony, investigated specifically in Dey 2015, pp57-64.

Ancient literary sources and artistic reliefs affirm that ingenious engineering solutions of Roman building had the power to draw large crowds of onlookers.[222] In large urban centers like Rome, with several thousand citizens likely to be in the direct path of transport avenues or ancillary support areas, lengthy processions of construction materials had the capacity to be choreographed as objects of spectacle. In addition to the thousands of cartloads of bricks and lime, the Basilica of Maxentius' giant 100-ton Proconnesian marble columns eventually shared the transport infrastructure. The minimum support requirements of each column demanded a train of oxen hundreds of meters long, and a plethora of drovers and materials. The scene created by shouting workmen, screeching pulleys, and rumbling streets was suitable to rouse significant interest by spectators. This particular parade of marble for the Basilica of Maxentius passed near the Circus Maximus and the Colosseum, Rome's iconic entertainment venues, and may have produced something rivalling processional fanfare.[223] The director of the itinerary manipulated the precise timing and route of each massive marble column, and staged each sequence as an event for the enjoyment and appreciation of the people of Rome. A potential parading of building materials indicates the tangible impact of the construction process on the social and physical networks of the city, and the resulting spectacle acts as an indicator for the degree of symbiosis.

The exact imaging of this spectacle is unclear, as no direct representations of construction tasks viewed by onlookers has been described or rendered. However, the propensity for and celebration of spectacle is certainly among the most investigated aspects of daily life in ancient Rome, and opportunities abound to recreate an environment for spectacular activity in the city

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[222] As evidenced in Vitruvius *De Architectura* 10, and the Haterii Relief, among others.

[223] The length and width of the specific oxcart train necessitated for the construction of the Basilica of Maxentius, discussed below, would actually dictate or insist that former triumphal routes would be utilized, based on the allowances provided. Thus, the analogy to "triumphal" processions is implicit in the logistics and specified construction procedures.

center.[224] Even though the tenor of the Roman worksite and most of the singular construction tasks are well understood, images of architectural design and manufacture pale in comparison to both realistic and idealized versions of the completed products. Although finished buildings act as the universal standard in Roman architectural rendering, the variability of the construction process dictates the final form of the structure, thus affecting representation of architecture in paintings, reliefs, or coins. There have even been commemorative images of unfinished buildings struck on coins which only loosely capture the appearance of the completed building.[225] This circumstance may be due to ancillary concerns such as miscommunication or artistic license, but it also may be caused by substantive changes to the monument during construction. The representation of construction and process by artists is thus a primary concern in the study of ancient architecture. In addition to the value allocated to concurrent literary accounts, artistic rendering allows further access to the subjects that artisans choose to depict. Scenes of worksites, materials transportation, construction implements, and buildings under construction prove the value of understanding this crucial component of ancient building culture. This study culls the imagery of both Roman spectacular elements and building technique to create a speculative hypothesis for construction spectacle.

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[224] See Dodge *Spectacle in the Roman World*, London: Bloomsbury, 2011, and privilege given to the spectacular in Carcopino 1940 and Casson *Everyday Life in Ancient Rome*, Baltimore: Johns Hopkins University Press, 1998 (orig. 1975).

[225] Relevant examples of costly or well-known projects struck on coins but left unfinished at time of striking (or indefinitely) are two aqueducts in Nicomedia, see Price and Trell *Coins and their cities: Architecture on the ancient coins of Greece, Rome, and Palestine*, Sarzana: Vecchi, 1977: 11f, also Pliny *Epist*. 10.37; also on the "Temple of Augustus" in Rome and the Temple of Divus Claudius in Camulodunum, in Paul and Ierardi eds. *Roman Coins and Public Life Under the Empire*, Ann Arbor: University of Michigan Press, 1999, p111. Some Roman political figures probably planned to commemorate monuments on coins before they were finished, in order to project an image of interest in a building program, or to ensure that the public remembered their efforts.

3.2. Admitting late- and post-Roman comparanda as evidence for construction spectacle

In order to create a hybrid hypothetical model of Roman construction spectacle, this study will necessarily rely on notable secondary and tertiary sources that exist far outside of the traditional ancient archaeological canon. This method assumes that in an urban environment framed by similar variables, and employing like materials or technologies, construction has the capacity to be imaged in hermeneutically similar ways. The most valuable comparanda are derivative of the period of ancient Rome, whether they are found in the Roman cities in the Italian peninsula, or further afield in Roman provincial territories like Asia Minor, Greece, or Egypt. Accounts from the maneuvering of the Colossus of Nero to the erecting of Constantine's monoliths in his new capital provide a look at the likelihood of spectacular moments in architectural building. However, several other examples of construction imaging can be found in strikingly similar building situations, albeit found only by traversing geographical or temporal lacunae. Specific examples from medieval and modern Rome perhaps provide the best comparisons, as sometimes these later builders moved the exact same materials erected by their distant ancestors.

Rome is famously filled with obelisks and columns that have been placed and replaced over the centuries, and each movement of such immense monoliths has evidently drawn some sort of interested crowd. The building boom of the late Renaissance was responsible for several large-scale construction projects, including the well-documented transport and re-erection of the "Vatican obelisk" in 1585 CE.[226] Domenico Fontana orchestrated the transport of this 330-ton Aswan granite obelisk through a quarter-mile of Roman streets from the former circus of Nero to the Piazza San Pietro, and five years later penned the manuscript *Della Trasportatione*

[226] Also notable was the large crane for the raising of the Column of Antoninus Pius by Pope Clement XI in the Campus Martius in 1705, which was recorded by Arnold van Westerhout and published in 1762.

dell'Obelisco Vaticano.[227] The illustrations of Natale Bonifacio prominently display the crowds of interested onlookers, inexorably portraying the event as worthy of spectacle (see Figure 17). According to the manuscript, the entire operation was carried out in five months by employing 40,000 pounds of hemp rope and iron bars, 900 men, 72 horses, and one captivated city. Thirty years later, Pope Paul V moved the final extant column of the Basilica of Maxentius to the Piazza Santa Maria Maggiore, but the lack of an eyewitness account or contemporary illustration effectively steals an invaluable tableau for understanding transport in the Roman central city.

Figure 17: Sketch by Bonifacio from Fontana's manuscript depicting 330-ton Vatican obelisk being raised in 1585.

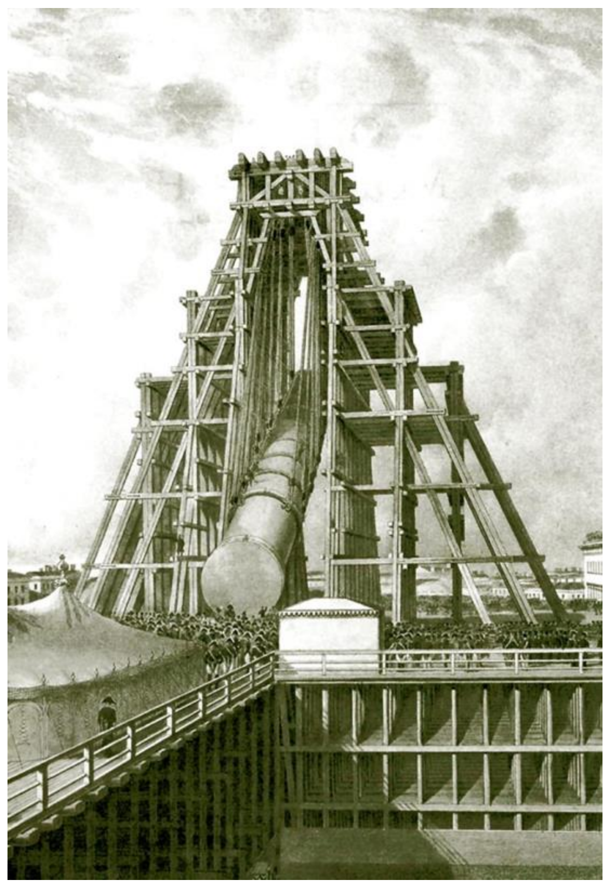

Figure 18: Sketch recording Montferrand's system for raising columns in St. Petersburg in the 1800s.

A more modern example indicating the difficulties, cost, and spectacle of moving large building materials is Auguste Montferrand's ambitious program for Alexander's Column in St.

[227] Caruga ed. *Della Trasportatione dell'Obelisco Vaticano et Delle Fabriche di Nostro Signore Papa Sisto V Fatte Dal Cavallier Domenico Fontana, Architetto di Sua Santita, Roma 1590,* Milano, 1978.

Petersburg, Russia in 1832 (see Figure 18).[228] This 600-ton column required two and a half years from its inception as a custom order from Finland to its erection in the city center. The project employed over 2090 soldiers, officers, and professionals, and by the final raising, its cost had doubled to over 2.36 million rubles. Several illustrations from the project imagine a massive spectacle carried out in front of thousands of people. Another project that has recently tested the potential for material transport spectacle is the 2006 conveyance of an 83-ton statue of Rameses II down two kilometers of urban Cairo avenues to its new home near the Great Pyramids of Giza. Here, the 10-hour parade of the statue on flatbed trucks was witnessed by tens of thousands of people, and broadcast publicly on Egyptian television.[229]

A contemporary analog for the celebrated transport of a massive raw material is provided by the 340-ton granite boulder brought to LACMA for Michael Heizer's *Levitated Mass* project, which suffered from many of the same impediments as a Roman-era monolith as it made its 100-mile journey from quarries in Riverside, California to Los Angeles in 2012 (see Figure 19).[230] The journey was

Figure 19: 340-ton boulder for Michael Heizer's "Levitated Mass" project installed at LACMA in 2012. Photo credit Taiyo Watanabe for Arrested Motion.

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[228] Shuĭskiĭ, V. K. [Шуйский, Валерий Константинович] *Auguste de Montferrand: The story of the life and work* [Огюст Монферран: история жизни и творчества], Moscow: Центрполиграф, 2005.

[229] Anon. "Giant Ramses Statue Gets New Home," *BBC News,* August 25, 2006, http://news.bbc.co.uk/2/hi/middle_east/5282414.stm.

[230] See *Levitated Mass: The Story of Michael Heizer's Monolithic Sculpture*, Directed by Doug Pray, Los Angeles: Electric City Entertainment, 2013; Nagourney "Lights! Cameras! (and Cheers) for a Rock Weighing 340 Tons," *The New York Times,* March 10, 2012, http://www.nytimes.com/2012/03/11/arts/design/340-ton-artwork-arrives-at-los-

elevated to the spectacular by thousands of onlookers, national news outlets, social media, and happenings that were custom-created by admirers of the quasi-ceremonial parade of rock. Although these tasks have been performed in quite a different environment than ancient Rome, the conveyance and erection of large building materials have proved spectacular to an urban milieu that accepts and celebrates the spectacular. Even unfinished architecture has drawn worldwide interest, as exemplified by the tantalizingly incomplete Cathedral of Sagrada Familia in Barcelona, and the symbolic roadblocks which plagued construction of One World Trade Center in New York. The admittance of infrastructural and construction processes into the realm of the spectacular is certainly not relegated to modern obsessions over unfinished projects, but finds proof in the witnessing, expressing, and imaging of this spectacle in ancient evidence as well.

The following investigation tests the notion that the process of Roman construction was watched intently by the populace, and surmises the various tasks that provide the opportunity for greatest spectacle. The presented hypotheses are tested against the known imaging of spectacular construction tasks and processes over a broad swath of historical episodes, while also exhibited with respect to proper analogs within the Roman world. Known quantities, material costs, and verified construction phasing are assets when dealing with the Basilica of Maxentius, but several variables require appropriate speculation and reconciliation with the overall image of building. An appropriate picture of the Roman construction process and the way it functioned with respect to the urban environment and its populace is a testament to the idea of a mutually beneficial symbiotic relationship, and the spectacular quality of construction events are the most poignant method of depicting this affiliation. While the infrastructural pathways leading from the quarries

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angeles-county-museum-of-art.html?_r=0; and Vankin and Sahagun "Giant rock ends its journey to LACMA," *The LA Times*, March 11, 2012, http://articles.latimes.com/2012/mar/11/local/la-me-0311-lacma-rock-20120311.

and manufacturers to the ports and staging areas presented several avenues for the spectacular, the construction site and the city of Rome itself are the most effective proving grounds.

3.3. Early activity at the worksite, construction traffic, foundational works

The construction process for the Basilica of Maxentius necessitated two distinct but interrelated classifications of raw materials that arrived at the building site. In simplified terms, the first class was the eight large and unwieldy Proconnesian marble monoliths, and the second was comprised of every other small-scale component element of brick-faced concrete vaulted construction. Although smaller by individual cartload, these components provided a far more robust contribution to the project by sheer volume. This contribution was comparatively easier to manage than the larger raw materials, due to the basic fact that the transport of a singular cartload repeated thousands of times along the same route has fewer margins for error than even one several-hundred-foot-long oxcart train. The basilica required eight such processions. Maybe the most poignant example of the symbiotic relationship within the city is the allowance of both singular large-scale material processions and multiple smaller-scale material transport to be enabled at the same juncture of construction.

The mobilization of materials for the basilica’s towering vaults and central hall caused a great stir in central Rome, and the first months of assembly quickly stimulated the construction industry. Given the project’s vital location between the southern Forum and the Colosseum Valley, the workaday populace could hardly ignore the onset of each new building phase. The first series of construction tasks were extremely abrasive and intrusive, consisting of demolition and excavation. The pre-existing Horrea Piperataria warehouses were torn down, but presumably not before their entire contents were emptied and carted off to a suitable location. Even before the inception of construction on site, these reappointment trips may have constituted the first real raw materials train on site, and began to crowd the streets of central Rome. After the cacophony of initial demolition, construction crews immediately began clearing away the Velian hillside for the massive foundations of the Basilica, which included an excavation of the Flavian-Trajanic villa situated above it.[231]

The size of the building site successively grew, with simultaneous provisions made for the construction of the small Temple of Romulus to the north and the reconstruction of the Temple of Venus and Rome to the south. Although the basilica was physically constrained by the existing Templum Pacis and the platform of the Temple of Venus and Rome, the construction site and material staging areas severely compromised all of the perimeter roads, including the Via ad Carinas, Via ad Compitum Acilii, and Via Sacra. The plethora of materials required for the masons to construct the massive basilica far exceeded the area immediately surrounding the building site, and as a result, must have inundated the rest of the central city. The Forum and the Colosseum Valley would be likely staging areas for materials and implements, but this naturally depended on the ability to shut down these sections for a period of months or years at a time. Several weeks before actual construction of the basilica would begin, the site had already accommodated demolition, excavation, and foundational tasks, which consisted of a possible provisional organization of the site, several different building crews, hundreds of cartloads moving in and out of the effective area, minor (raw materials for concrete foundations) and major (tufa foundational blocks) material staging. The transportation of larger tufa blocks may have prefigured the route of larger materials to come, depending if the origination point was the Emporium warehouses or the identifiable quarries south of the city.

[231] Giavarini 2005, pp21-23.

The continuous multi-directional running of materials, carts, and laborers from the construction site to staging areas, storage facilities, manufactories, and quarries was undoubtedly a large disruption to everyday life in the business district, if not the entire city. However, the monotonous commotion associated with clearing foundations, laying bricks, and composing concrete would pale in comparison with the spectacular rumble of heavy stone monoliths down Rome's cobblestones. By the time of the basilica's construction, it had been nearly 100 years since the emperor Septimius Severus had last brought colossal marble columns into the center of Rome, and this new occasion took on a ceremonial aspect.[232] In replicating the act of transporting and raising large marble columns in central Rome, Maxentius was able to link his new brand of construction spectacle to Severan, and even Hadrianic or Trajanic methods of punctuating imperial building projects with massive monoliths.[233]

That construction was underway in the entire area bounded by the southern Forum, the Palatine Hill, the Imperial Fora, and the Colosseum functioned as a long, sustained declaration of production activity.[234] The syncopated clang of hammers and the coordinating shouts of workmen overtly signaled the construction tasks. It had been decades since the center of Rome was last alive with the din of construction, and passersby periodically stopped their work to

[232] The last known instance of large-scale marble monolithic columns that were brought into the central city area and erected on a monument in or near the Forum was the Arch of Septimius Severus, with a construction date of 203 CE. The arch has eight marble monoliths that stand 8.78 meters high and 0.90 meters in diameter at the base. See *LTUR* 1, pp103-105 and Platner and Ashby 1929, pp43-44. There have been no other major projects in the Forum identified between the construction of the Arch of Severus and the Basilica of Maxentius. There may have been reconstruction projects that required columns, including the portico of the Curia Julia, which was restored after the Fire of Carinus in 283 CE, but at this point it is difficult to conclusively posit a larger-scale exhibition of marble columns. This relative disuse of the Forum for new projects may have actually made it easier to stage materials and build new architecture in the area.

[233] This culmination of a large-scale building program in the city and replication of Severan/Hadrianic/Trajanic building methods would possibly become more poignant if considering the hypothesis addressed in the following section, that Maxentius may have spoliated Hadrianic-era columns to punctuate the Basilica of Maxentius.

[234] See visual evidence for construction sites, *Scene of a building site*, painting from Stabiae (Archaeological Museum of Castellmare, no. 282); *Scene of a building site*, relief found at Terracina (National Museum of Rome).

check on the progress.[235] The populace of Rome undoubtedly missed the long-departed days of frequent spectacle in the city center, and surely the promise of eight massive marble columns for a prominent new building in the Forum was a powerful prospect.[236]

Rome had always enjoyed a public exhibition, from speeches to games to ritual processions.[237] The people of Rome were fanatical about spectacle, and during the days of the Empire, they turned out in great numbers whenever a procession was announced. Plutarch recalls one such episode from the Republican triumph of Aemilius Paullus,

> "The people erected scaffolds in the forum, in the circuses, as they call their buildings for horse races, and in other parts of the city where they could best behold the show…all the temples were open, and full of garlands and perfumes."[238]

The citizenry of Rome appreciated a choreographed show, and the best staged views were habitually revered by patrician and plebeian alike.[239] On the days that the massive columns were towed to the building site, the capacity for spontaneous spectacle was readily apparent.[240] It is unknown if the laypeople were made aware of any particular aspect of the building schedule in

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[235] The last major project in the city center was the reconstruction of the Curia Julia by Diocletian in the 280s.

[236] This circumstance was rendered even more prominent considering that Diocletianic reforms had essentially demoted the urban population of Rome to second-class citizens. The Tetrarchy had moved the Imperial capital away from Italy, which reduced Rome to the tax status of a province for the first time in its history. This must have come as an unimaginable surprise to the populace, who still cultivated the age-old traditions of the senate, who ratified and sanctioned events such as triumphal processions and public building projects.

[237] For a discussion of Roman interest in spectacle, see Carcopino 1940, pp202-206. Further discussion of leisure and interest in spectacular games contained in Toner *Leisure and Ancient Rome*, Cambridge: Polity Press, 1995, specifically Chapter 5: Blood, Sweat, and Charioteers – The Imperial Games and Chapter 7: Goodbye to *gravitas* – Popular Culture and Leisure; also Coleman "Entertaining Rome," in Coulston and Dodge 2000, pp210-258; Purcell "'Romans, play on!' city of the Games," in Erdkamp 2013, pp441-460; Dodge "Building for an Audience: The Architecture of Roman Spectacle," in Ulrich and Quenemoen 2014, pp281-298; Casson 1998 (specifically Chapter X: Fun and Games, pp98-108); Dodge 2011.

[238] Plut. *Aem*. 32.2.

[239] A discussion of Roman perception of festivals is contained in the 'Seeing the festival' subsection in Favro "The Festive Experience: Roman Processions in the Urban Context," in Bonnemaison and Macy eds. *Festival Architecture*, New York: Routledge, 2008: pp14-22.

[240] On this point, see the above discussion of the *Levitated Mass* film, where spontaneous spectacle was a large part of the total experience of the 343-ton boulder's journey to from quarry to site.

advance, but judging by Maxentius' program of renewing the former greatness of Rome by virtue of architectural magnificence, one can speculate with some confidence that this event was strategically manipulated for spectacular value. Even if the schedule was not posted or the town crier was not tasked with making an announcement, the road closures, amplified presence of workmen along transport routes, and disruptive rumbling of the streets would indicate that a parade of marble columns was quickly approaching.[241]

3.4. Competing hypotheses for column delivery: direct order or spoliation

Although the current archaeological state of the site is notably devoid of columns, the once proud existence of eight polished Proconnesian monoliths at the Basilica of Maxentius is attested by the sturdy remnants of their corresponding entablatures on the upper faces of the extant eastern side aisle, and the account of one last columnar movement to the Piazza Santa Maria Maggiore by Carlo Maderno and Pope Paul V in the 1600s.[242] The most important unknown variables at issue are the initial origin of the columns, the path of travel necessary to arrive at the building site, and the specific moment of appearance relative to the construction phasing. The provenance of the Proconnesian columns definitively locates their formation in the Hellespont, but they may have arrived in Rome at any time relative to the Imperial exploiting of Mediterranean quarries. The eight columns were once portaged along the trade network lanes of construction infrastructure, but their arrival at Rome's marble yards is difficult to securely ascertain. The columns may have been ordered and shipped directly from their source, and

[241] In Sen. *Ep.* 56, the author notes the great noise from a simple passing carriage. A larger *plaustrum* wagon for construction materials may have created a further nuisance, and the exponential numbers of wagons would amplify the sound reverberation. The noises from the many carriages rumbling along these routes would undoubtedly have the power to rouse anyone in the near vicinity, and this noise might have trumped the normal construction noises from the Forum as well.

[242] Referenced in Hibbard *Carlo Maderno and Roman Architecture, 1580-1630*, London: Zwemmer, 1971, p235.

scheduled for timely delivery to the Basilica of Maxentius. This would establish a secure timeline for on-site building, and allow for a hypothesis of their route from storage yards to site.

However, a competing theory for the columns' arrival has been introduced by Taylor in his recent article concerning the study of Hadrian's Serapeum on the Quirinal Hill.[243] Taylor suggests that the eight columns had a more circuitous journey from the quarry to the basilica building site. Based on a hypothetical discussion of the complicated needs of 2nd-century Hadrianic construction in the city center, Taylor posits that the columns were originally intended to rise in the porch of the emperor's often-misunderstood new construction in the Campus Martius. According to Taylor's theory, the porch of the Pantheon was originally planned to accommodate the largest monoliths available at the time, comprised of a set of 54-foot Proconnesian column shafts. But the Hadrianic builders found that in practice the usual hoisting mechanisms were impossible, and even the adjustment to using tilting mechanisms failed to successfully erect the dense collection of monoliths in such a cramped space.[244] Thus, the logistical actualities of the Pantheon's construction process had effectively rendered the once-important building blocks useless. The columns were temporarily put aside, and likely stored in the Emporium marble wharves until a new project necessitated their reuse.

As Taylor assumes, a new confluence of needs arose quite quickly, and Hadrian was able to use the Proconnesian monoliths for his Temple of Serapis on the Quirinal Hill.[245] The noted

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[243] Specific hypothesis advanced in Taylor "Hadrian's Serapeum in Rome," *American Journal of Archaeology* 108, no.2 (April 2004): 223-266; see also Taylor 2003, pp129-32 for further analysis of the Pantheon.

[244] This specific theory by Taylor posits a new interpretation of how the porch of the Pantheon was adjusted, and led to the slightly faceted connection of the porch to the impost block. The previous interpretation, advanced by Wilson Jones 2000, pp199-212, and by Davies, Hemsoll, and Wilson Jones "The Pantheon: Triumph of Rome or Triumph of Compromise?" *Art History* 10 (1987): 133-153, was that the originally-ordered column shafts for the Pantheon never arrived in Rome, and adjustments had to be made by scaling down the porch's height.

[245] Taylor 2004, p254; the confluence of needs included Hadrian's integral visit to Egypt and possible pledge for a Serapeum in Rome, a set of columns extant in Rome to employ in such a grandiose construction, and a workshop of Pergamene specialists able to carve the capitals into a suitable and elegant Asiatic style.

demise of the Serapeum in the later antique period suggests a contemporaneous spoliation of its columns, and Taylor argues that this material pirating may have occurred during the transitional period between Maxentius and Constantine.[246] Based on the assumption of the Serapeum's demise during the 300s, and the similarity of its Asiatic style to the last existing Maxentian-era column in order, decoration, and size, Taylor suggests that the last undamaged and unfettered eight of the initial sixteen Proconnesian monoliths were transferred from the Quirinal Hill to the Basilica of Maxentius in the first decade of the 4th century. This hypothesis assumes that Maxentius' desire to quickly establish himself as *conservator urbis suae* meant a possible subversion of the usually lengthy ordering process for colossal marble columns, and instead a swift spoliation of a known quantity.[247] The process would surely provide the desired means faster, but the conveyance of the columns from the Quirinal would face similar difficulties of portage from the Emporium. In some cases, the obstacles would be more severe, and the results harder to achieve.

In fact, any attempted route from the Temple of Serapis to the Basilica of Maxentius was likely so convoluted that the planners must have considered other options, such as a virgin order from the Hellespont. The location of the Serapeum, even given its position near the southwest end of the Quirinal Hill, was on the opposite side of both the Imperial Fora and the Subura. The impending calamitous spectacle of transporting eight 54-foot columns through the dense mass of the Subura is an entertaining thought, but unfortunately not at all likely (see Figure 20). More realistic was a re-routing of the monoliths through the open spaces of the Fora of Trajan, Augustus, Nerva, or the Forum Pacis. Each of these options would be dependent specifically on

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[246] Most notable in Taylor 2004, p260 is the lack of mention of such a grand large temple in the visit of Constantius (and his biographer Ammianus Marcellinus) in 357 CE. The Serapeum, Taylor argues, must have been almost the size of the Temple of Venus and Rome, and surely worth a visit if it was extant at the time. Thus, it must have been spoliated before this visit.

[247] See Cullhed 1994.

the degree of difficulty of fitting the oxen trains through suitable arcaded openings in façades. The resulting display of large building materials in open public spaces is in essence a spectacular occurrence, and was likely to be witnessed by a plethora of Rome's plebeians.

The spectacular celebration of large-scale materials' transport, arrival, and erection is a pointed example of the visible slippage between the city organism and the basilica's construction process. Either an additive order of new columns for an architectural project, or a re-appropriation of spoliated columns from a constituent part of the city can be viewed as basic functions of an organic entity seeking growth. The success of either maneuver is further proof of

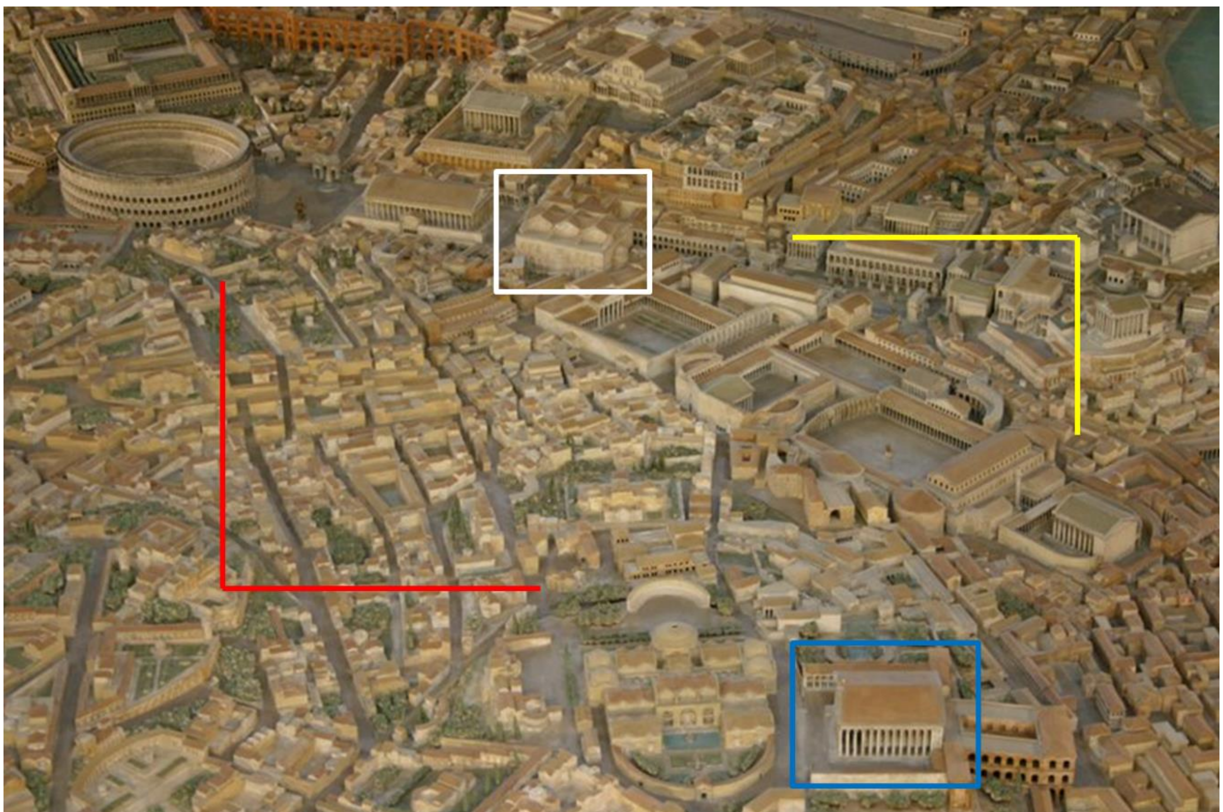

Figure 20: Detail of *Plastico di Roma Imperiale* model (I. Gismondi: Museo della Civiltà Romana, 1933-1955). White indicates the Basilica of Maxentius. Blue indicates the Hadrianic Temple of Serapis. Red indicates the dense area of the Subura. Yellow indicates the Imperial Fora, including the Forum of Trajan and Forum of Augustus. Any material transfer between the two monuments would likely have to travel through either the Subura or the Imperial Fora, with the latter being more likely.

an effective symbiotic relationship between process and city. In the following analysis, both possibilities will be briefly explored, with neither option taking full precedence over its counterpart. The parading of marbles through the public spaces of Rome revealed the current state of symbiosis, and the endpoint at the building site acted as an appropriate confluence of all of the logistical infrastructures.

3.5. Logistical planning, routing materials, and managing the payloads

The successful and timely arrival of all building materials on site was a logical goal of the basilica's planning team, but admittedly the height, weight, heft, and unwieldiness of the eight Proconnesian monoliths necessitated a more careful program to ensure completion. The timing of their arrival coincided with the ability to physically fit them through appropriate openings in the structure of the basilica, and erect them inside the central hall. The columns themselves would not be load-bearing for the vaulted hall, which allowed for a bit more maneuverability then would be expected in a standard post and lintel construction type. Structurally speaking, the columns could have been placed after the central vault had been carried out, but in practice, several other factors made that scheduling impossible. The short (eastern and western) sides of the basilica held a great deal of the central vault loads, and the longer (northern and southern) sides held the aisled barrel vault loads. This meant that the columns must have been taken through to the floor of the basilica before both the central vault and at least one set of the three barrel vaults had been carried out.

The most likely scenario was to erect the exterior walls and barrel-vault piers of the northern side, and then bring the columns for the north side of the central hall through the still-

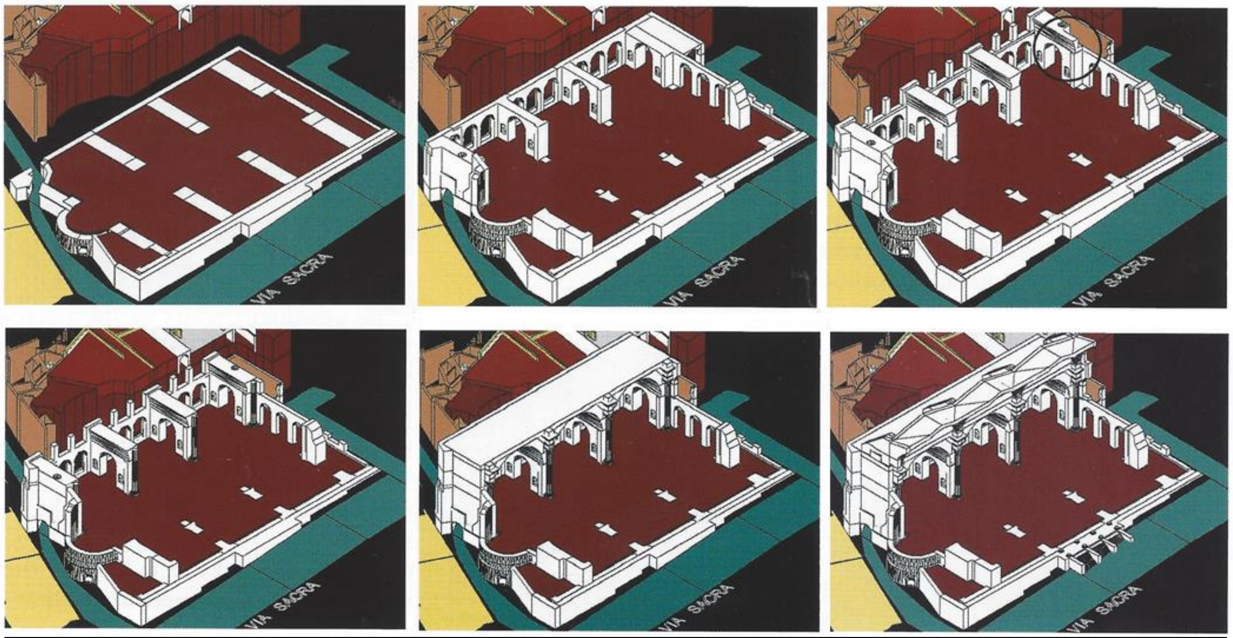

Figure 21: Basilica of Maxentius building procedure schematics reproduced from Amici in Giavarini 2005 (Plates 9, 16, 18, 23, 29, and 31, pp152-158). At top left, the Basilica is shown at foundation stage, top center displays the formation of the northern walls, top right displays the construction of piers, bottom left displays the placement of columns at piers, bottom center displays columns with capitals and entablature, bottom right displays full layout of northern walls and vaults.

open southern side (see Figure 21).[248] The columns adorning the opposite southern end of the central hall were also brought through during this phase, and stored in an area of the floor that was unfettered by other material staging. The barrel vaults of the north side were then completed, and the columns were put upright, perhaps by using the extant walls as anchor points for the lifting mechanisms. The construction of the southern side could only proceed after the large

[248] This sequencing agrees with Amici "Section 5.5. Building Procedures" in Giavarini 2005, pp149-160. Amici uses an examination of the facings and articulation of the extant northern walls of the basilica to arrive at the conclusion that the northern wall and piers were erected before the columns were brought in. Specifically, Amici's plates 7-31 on pp152-158 indicate the exact sequencing needed (several of which are reproduced in Figure 19). The columns for the northern end of the central vault would be erected first, then the northern barrel vaults completed over the top. Amici does not postulate on the construction of the opposite end of the basilica, as it no longer exists archaeologically. It stands to reason that the columns for the southern end of the central vault were also brought in at the same time and stored until their use. The completion of the southern end in the same manner as the northern end would make this necessary, as the access point for the columns would no longer exist when the southern end was complete.

column payloads had been directed securely across the void of the southern threshold. Once the marble monoliths were clear, the southern walls and piers could then be built, as their prior absence would now be rendered unnecessary. The smaller payloads of materials for concrete-vaulted construction could sufficiently move in and out of openings built into the shorter eastern side, as could the supporting materials for the columns and other building implements. As a result of this phasing, the columns would arrive on site to only a one-third-finished building, which inherently maximized their maneuverability.

The maneuvering and manipulating of the monoliths would prove to be far easier inside the confines of the massive basilica than in several of the areas and roads on their journey from their storage source. As discussed, the basilica's eight columns were either ordered directly from Proconnesus and stored temporarily at the Roman marble wharves along the Tiber, or were instead spoliated and originated at the Temple of Serapis on the Quirinal Hill. Both of the possible itineraries would hold distinctive routing challenges, but the former commencement point had been employed as Rome's principal material distribution yard from its inception during the Republic. All material supply trains initiated at the Emporium had the benefit of being preceded by thousands of other such successful journeys through a city characterized by eternal building. The oft-repeated experience of levying large marbles from the Emporium substantially benefitted the porters of the Imperial era, and the specific routing in the direction of the Forum Romanum had likely been a stalwart for three centuries. However, the roughly two-kilometer journey from the material warehouses along the Tiber to the Basilica of Maxentius building site was still inherently difficult (see Figure 22).[249]

[249] The following map analysis is carried out in reference to the following sources: Franciscus Scagnetti's map *Roma Urbs Imperatorum Aetate* Rome 1979; Forma Urbis Romae [FUR] fragments, most notably in Meneghini and Valenziani *Formae Urbis Romae: Nuovi Frammenti di Piante Marmore e dallo Scavo dei Fori Imperiali*, Rome: "L'Erma" di Bretschneider, 2006, Chrystina Hauber's map *Das archaische Rom innerhalb der spateren*

The chosen route had to confront the meandering and organic system of Roman streets between the sizeable physical obstacles of the Aventine, Caelian, and Palatine Hills.[250] The Aventine Hill was a topographically and physically dense area that was nearly impossible to

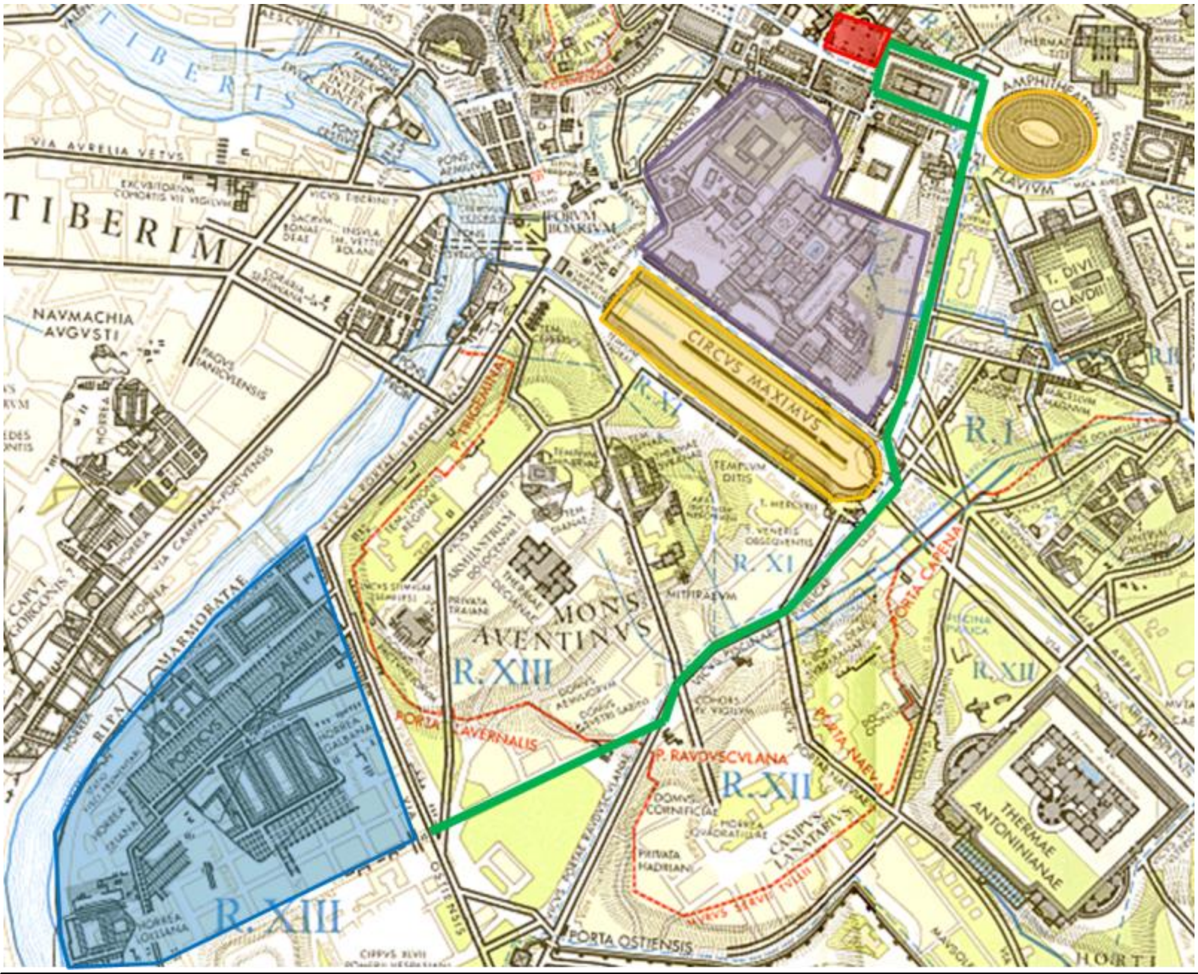

Figure 22: Southern quadrant of Imperial Rome. Red indicates Basilica of Maxentius, blue indicates the Emporium marble yards, green indicates the route pursued from storage to site, yellow indicates the Colosseum and Circus Maximus (two of the city's entertainment venues, purple indicates the Palatine residences. Map credit: Scagnetti *Roma Urbs Imperatorum Aetate*, Rome: Staderini S.p.A., 1979.

Stadtmauern (Rekonstruktion mit dem AIS ROMA) 2013, http://www.rom.geographie.uni-muenchen.de/index.html, and *Rome City Map* –Map A, p173 in Wittke and Salazar eds. *Brill's New Pauly Historical Atlas of the Ancient World,* Leiden: Brill, 2010 (with contributors Kardos, Castagnoli, and Coarelli).

[250] The Aventine and Palatine Hills lie directly in the vector from the Emporium to the Basilica of Maxentius, as the crow flies. The Caelian Hill borders on a possible route formulation, and defines the edge of the so-called Via Triumphalis from the Circus Maximus to the Colosseum. A fourth hill that could have affected material travel is the Capitoline, but its existence to the north of the Forum Boarium makes it unlikely to affect routing in this instance.

breach with construction traffic, and the Caelian Hill formed an eastern border to the lower-lying valley between the two hills. The breach between these two hills was a likely route for larger materials through the southern city. The dense Palatine residences lie to the direct southwest of the building site, and the Velian Hill and Subura residential area immediately to the northeast. In addition, the urban topography at both the northwestern and southeastern end of the city center was extremely dense, and yielded only a few additional avenues.[251] Confronted with this dilemma, Maxentius' planners were likely forced to choose from two routes, with the first following the slight curve of the Tiber and eventually approaching the site from the Forum, and the second utilizing the "Via Ostiensis" southwards and approaching the site from the Colosseum Valley (both routes are depicted in Figure 16, while the latter route is investigated in Figure 22). The approach via the Tiber would necessitate either a brief ferrying of the columns in the waters of the river, or a more likely street conveyance along the "Vicus Portae Trigeminae" along its banks. The columns would then need to pass through the lively Forum Boarium and its indeterminate dirt surface, and negotiate a series of smaller winding streets (likely the "Vicus Tuscus") to get to the entrance of the Forum near the Basilica Iulia.[252] The column porters would then need to interrupt the activity of the Forum and pass through its eastern side towards the building site.

Instead, the directionally opposite approach began by moving from the Emporium down the well-traveled "Via Ostiensis" towards the relief point in the piazza preceding the Porta

[251] Based on the vector from the Emporium marble yards to the building site, the route would move north or south around the Aventine and Palatine Hills; even if there was another marble yard in the Campus Martius (an idea which Maischberger 1999, pp325-334 discounts), the route from the Emporium district would still appear to be easier to traverse than moving through the area of central Rome to the Forum.

[252] The route through the Forum Boarium would function as a relieving element for this particular segment, because the streets along the Tiber and leading to the Forum Romanum would essentially open up into the former "cattle market." The relief would be impermanent, although allowing drovers to steady or re-orient their loads and pack animals.

Ostiensis. The route then turned east to follow the "Vicus Portae Raudusculanae" and the "Via Piscinae Principalis" through the gap between the Aventine and Caelian Hills. At this point, the columns would reach the piazza between the old Porta Capena and the southeastern promenade of the Circus Maximus. This open area functioned as the first real visual showcase for the massive exotic marbles, and provided an intriguing confluence of Rome's foremost entertainment venue and the opportunity for exhibition of Maxentius' construction materials. As the columns approached from a southwesterly direction, there was no need to actually enter the Circus Maximus to show off the columns, as the neighboring piazza furnished enough room for any interested viewers. However, if the columns had instead been ferried or portaged along the Tiber to the Forum Boarium, they may have then entered the Circus and traversed its length to reach the piazza of the Porta Capena.[253] In this case, the wide berth of the racetrack and the large *cavea* seating sections afforded by the Circus would provide a spectacular display for onlookers.

Upon their exit from the Circus Maximus, the columns were pulled down a long straightaway in the so-called "Via Triumphalis," and enter the Colosseum Valley from the south. This length of road has the quality of linking the two most prominent entertainment venues in Rome, and duplicating the route of Roman triumphal processions. Logistically, an oxcart train of great length would take advantage given such a wide berth. The slight incline of the Palatine and Caelian Hills along this street even afforded the possibility for erecting temporary stands for interested viewers.[254] After the relatively easy passage up the "Via Triumphalis," the columns

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[253] The idea of routing the columns from the Emporium along the shores of the Tiber, through the Forum Boarium, and either through or along the Circus Maximus is also posited by DeLaine 1997, p100, as it applies to the building of the Baths of Caracalla. If this procession had indeed been an actual Roman Triumph, it was a foregone conclusion that the route would be altered for maximum viewership. Here, it is only speculation.

[254] The circumstance of erected temporary stands for Roman events has previously been discussed, with regards to the line from Plut. *Aem*. 32.2. It is increasingly likely that stands would have been erected along the so-called "Via Triumphalis" during Roman triumphal parades dating back to the Republican and early Imperial periods. Whether the parading of marble for an important Imperial construction project would compare in magnitude to those triumphal parades is arguable, but the total length of the processional would indeed be comparable to a triumph.

would then be turned ninety degrees and head up the Via Sacra across the Velian Hill spur to the building site. The columns would pass in front of the Colosseum and in close proximity to Maxentius' construction of the Temple of Venus and Rome, which were very visible nationalistic symbols of Rome. This routing would draw significant interest, and spotlight a tangible symbiotic cooperation between logistics and spectacle.

A similar logistical test would be provided in the event that the Basilica of Maxentius spoliated the columns from the Temple of Serapis on the southern end of the Quirinal Hill. The initial investment would have been much greater here, as the planners had to physically remove the columns after the presumed destruction of the temple in a fire, and ready them for movement through a problematic section of the city.[255] Although Taylor admits that the *cella* may have remained in use, the porch was damaged irreparably and the columns ripe for spoliation. This

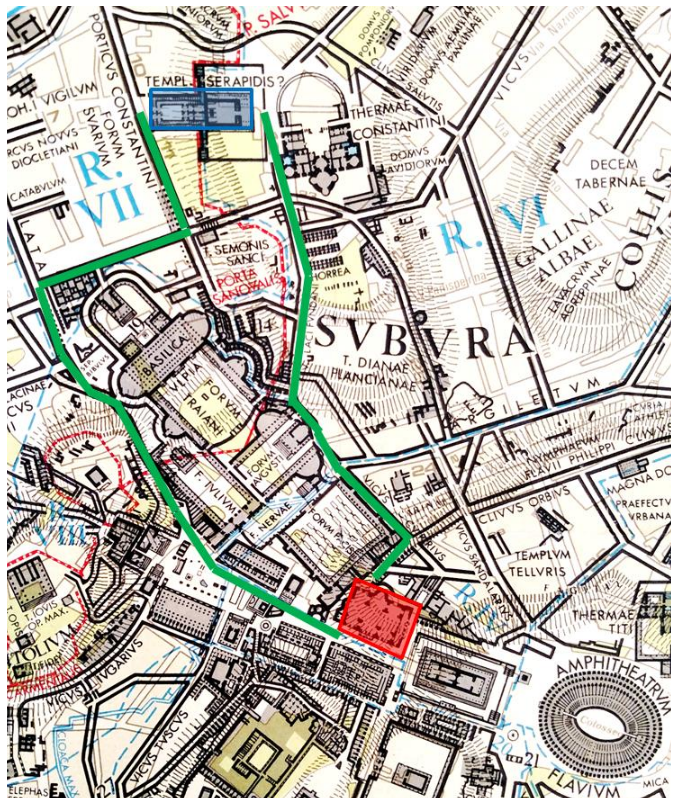

Figure 23: North-central quadrant of Imperial Rome. Red indicates the Basilica of Maxentius. Blue indicates the Temple of Serapis on the Quirinal Hill. Green indicates the two possible routes of travel for the eight monoliths. Map credit: Scagnetti *Roma Urbs Imperatorum Aetate*, Rome: Staderini S.p.A., 1979.

[255] The energy required to loosen and remove the columns, take them down, ready them, transport them, and then re-erect them would have been significant; possibly more significant would be the religious ramifications of spoliating temple columns. Taylor 2004, p263 suggests that a fire (perhaps that of Carinus in 283 CE) ravaged the Serapeum, and rendered it a "hulking wreck on the Quirinal Hill."

circumstance would make it a bit easier for Maxentius to raid the eight Proconnesian monoliths without causing dissent on religious grounds. However, it is interesting that instead of attempting to restore the entire Serapeum by employing the still-intact columns, Maxentius elected to parade them through the middle of Rome to his new creation south of the Forum. The columns' travel southward down the Quirinal Hill is specifically impeded by several major obstacles, including the complicated topography of the Imperial Fora immediately to the south, the small but contoured Arx and Capitoline Hills to the southwest, and the Subura down the south slopes of the Quirinal (see Figure 23). The Subura was the densest area of habitation in Rome, and the meandering streets and detrimental impenetrability of this urban zone likely forced the columns to circumnavigate the entire area.[256]

The most direct route from the temple to the basilica followed the southern plateau of the Quirinal along the "Vicus Laci Fundani," skirted the western edge of the Subura, and passed behind the Markets of Trajan, the Forum of Augustus, and the Forum Pacis on the "Vicus Cuprius." The columns would thus continue towards the basilica from the northern side, which would be the more difficult of the two directions of approach given the known phasing of construction proceeding southwards. Possibly a more sensible channeling of the monoliths would be through a combination of spaces in the various Roman Fora. In order to achieve this, the columns were transferred from the Temple of Serapis westward down the Roman street established where the modern Via IV Novembre meets the Piazza Venezia, and approached the Forum from the north on the "Via Lata." The "Via Lata" skirts the edge of the Forum of Trajan, and then gives way to the tight "Clivus Argentarius" sloping downward past the Arx and into the

[256] The Subura was incredibly dense, smelly, noisy, and extremely difficult to maneuver, based on its reputation in literature; see *LTUR* IV, pp379-383. It was notoriously disliked by satirists like Juvenal, even referring to it as "the seething/fiery/raging Subura (*feruenti Subura*)" in *Satires* 11.51. The meandering nature of the neighborhood likely provided much of a detriment rather than the relative subsidies provided by other routes.

Forum. The columns would then lumber through the Forum and approach the basilica from the southwest, in a more advantageous manner than if they had traveled behind the Imperial Fora. The vast open space of the Forum would be a relief from the tighter spaces characterizing this route, and the overall distance covered is far smaller than the analog trip from the Emporium. Viewership of the Quirinal-Forum procession would be more difficult to arrange, so too would be the difficulty in conveyance. The opportunities for spectacle along either route from the Temple of Serapis would be slight, unless significant detours were created to divert the columns through the open spaces of the Forums of Caesar, Trajan, or Augustus. Any deviation is quite unlikely; significant modifications or temporary alterations would have been made to any of the Fora in order to create a wide enough berth for the train of oxen to enter and exit.

In determining any route for a procession of marble monoliths, it is important to note the variability in ease of transport, the geographical and topographical make-up of the areas, and the political aims of the imperial client. The spoliation of columns from a prominent Hadrianic monument would certainly ask the population of Rome to symbolically associate the two rulers with respect to their ambitious building programs, and their very public donations of architecture for the benefit of the city.[257] But an approach of the columns down the "Via Triumphalis" and the symbolic connections that accompany such a procession would achieve many of the same aims. The routing through the "Via Triumphalis" would be easier on the oxen train for three principal reasons: the turns are slight, the streets are wide, and the hills are less intimidating than

[257] Specifically, this argument has been made about the spoliation of several Hadrianic, Trajanic, and Aurelianic monuments for the Arch of Constantine. It is necessarily uncertain whether a tangible connection can be made between the spoliating emperor and the spoliated monuments, but likely that a symbolic connection was inherent in the re-carvings at the Arch. In this scenario, Maxentius may have alluded to the grandeur of a significant Hadrianic monument, *and* appear as a conservator by simply re-appropriating columns from a temple now tragically rendered unusable in a prominent fire. It is unclear if the populace of Rome would react favorably, but this action does inherently follow a similar trajectory of the other prominent elements of Maxentius' building program in Rome.

elsewhere in the city. The triumphal approach would also allow for a poignant connection to several other notable Roman buildings, and a more tacit celebration of the construction process.

Taylor's argument for column spoliation from the Serapeum is convincing, but it seems likely that a fire destroying that temple would render at least a few of the monoliths unusable. This fact, in combination with the difficulties of routing the cargo through the densest section of Rome, makes the scenario improbable. Maxentius had sought to establish himself as the sole Emperor of Rome, and the most convincing method of achieving this aim was to visually demonstrate his authority and reach. It was a powerful statement to acquire eight monoliths from within territories now governed by a neoteric Tetrarch, and parade them triumphantly through the streets of the former capital. Maxentius thus employed multiple arms of Imperial infrastructure, and transformed his city into a booming construction site.

In truth, the entire area from the Colosseum to the southern Forum was most likely appropriated for a variety of construction purposes. Bricks, lime, pozzolana, and other materials streamed into these areas daily, and were set up in a variety of staging areas. These areas would now either have to share functionality, or give up their position for the complicated train of colossal materials that was soon arriving. The routing was likely to give planners and designers much trepidation, because of the shutdowns and security mechanisms that needed to be employed. The determination of the route was discussed with the oxen drovers, who had been contracted explicitly for this purpose. Their input and expertise would likely anticipate specific problem areas and important junctions along the way.

Figure 24: Mussolini's monolith transported by oxen from Carrara in November 1928. Photo credit Hrand.

Assuming a procession originating from the Emporium, the drovers were about to negotiate two kilometers of cobbled Roman streets, with several turns and gradations of terrain. All of this was presumed to occur with little to no error. The penultimate step of readying the oxen, carts, pulleys, logs, and lifting apparatuses preceded only the strapping and securing of the monolith to its modified cart.[258] Laborers then darted in every direction readying the route, and eventually the oxen train would be able to traverse a clear path. The veritable parade of marble began with the coordinated emergence of a train of oxen hundreds of meters long, dozens of supporting teams, and a 15-meter-long marble column cradled tightly on sturdy carts (see Figure 24).[259] The height and girth of each column gives a total volume of about 35 cubic meters, and if marble weighs an average of 2.82 tons per cubic meter, the columns weigh about 100 tons.[260] Xenophon records that each yoked pair of oxen could carry just less than half a ton.[261] This estimation would necessitate at least 230 oxen pairs, with at least 1 attendant per each pair. Assuming that an average oxen pair with the

[258] The character of the workforce would be composed of drovers needed for each pair of oxen, foremen needed to supervise the entire operation (provided by marble yards or imperial design staff), workmen to steady loads as they are transported, and miscellaneous workmen to clear areas ahead and behind; in total the workers might number in the hundreds.

[259] In antiquity, transporting loads meant pushing, pulling, or dragging materials in a pre-industrial state; the concept of using oxen is widely accepted as the standard way to move loads, see Fitchen 1986, also consult Burford 1960; the oxen might also have been employed in combination with rollers and pulleys for uphill/downhill journeys, of which we have evidence from a court case in *Dig*. 9.2.52.2, in which a loose wagon ran down a hill and killed a slave boy.

[260] The columns are 14.7 meters high and 1.7 meters in diameter, which gives a total volume of 33.3 cubic meters.

[261] Xenophon *Cyr.* 6.1.52 records that each oxen yoke could carry 380kg (0.42 tons).

accompanying yokes measures about 2.5 meters long and about 2 meters wide, and that the oxen are run with two pairs side-by-side, the herd of oxen would be nearly 300 meters long. When adding in the length of the column and cart, these numbers suggest the possibility of a train length of over 320 meters. Spectators may not have witnessed the initial emergence of this procession from the Emporium warehouses, but the gradual materialization of such a long train of equipment became visually arresting throughout the remainder of the route.

3.6. Confronting the spectacular challenges of maneuvering, bottlenecking, and hoisting

Oxcarts and other construction vehicles had fortunately been afforded the luxury of traveling during daylight hours, as the *Lex Iulia Municipalis* limiting heavy traffic during the first 10 hours of the day did not apply to imperial building projects or demolition works.[262] Therefore, the peril of maneuvering 460 oxen and a 100-ton stone could at least be tempered with day-lighting. Nightfall would undeniably halt the marble procession, making the streets and building angles impossible to account for. For the most part, working in darkness should have been easily avoided. DeLaine estimates that heavily-laden oxen can move at an average of 1.67 kilometers per hour, and even a more conservative estimate places one marble procession securely in the space of a single 10- to12-hour workday.[263]

[262] DeLaine 1997, pp98-99 notes that the *Lex Iulia Municipalis* is our only source detailing the use of heavy cart traffic in Rome; the Law (*Tabula Heracleensis* vv. 56-61) states no heavy traffic for the 10 hours after sunrise, excepting for imperial building projects or demolition works. Kaiser "Cart Traffic Flow in Pompeii and Rome," in Laurence and Newsome 2011, pp174-193, notes that the law may only have applied to certain types of vehicles, which would function to loosen the regulations pressed onto large material carts. Kaiser also notes that it may have been the prerogative of local neighborhoods to regulate traffic flow through their streets, which may have then been complicated by municipal magistrates and Imperial building projects superseding that control.

[263] DeLaine 1997, p98; other figures on the length of the workday provided by Pegoretti (rev. Cantalupi) *Manuale pratico per l'estimazione dei lavori architettonici, stradali, idraulici e di fortificazione, per l'uso degli ingegnieri ed architetti*, Milan 1869, p13, Demarchi *Cave di pozzolana nei dintorni di Roma*, Rome, 1894, pp12-13, Burford 1960, p247, and Roder "Die Steinbruche des numidischen Mamors von Chemtou" in Rakob *Simitthus I: die Steinbruche und die antike Stadt*, Mainz am Rhein: Verlag Philipp von Zabern, 1993, pp47-50.

The two-kilometer route was mostly filled with straightaways for the train to lumber steadily along, but the oxen and drovers did need to periodically rest and eat during the day. There were also several possibilities of delay during the trip, including misbehaving oxen, difficulties negotiating turns, breaches of safety perimeters, bottlenecks at critical junctures, and broken or faulty equipment. Any of these risks tested the symbiosis of the entire system, and could create a delay in the transferring of the marbles. The planners tried fastidiously to achieve the journey from storage to site in one working day, because of the desired safeguarding of the loads at the originating and terminating end. There was a large degree of irresponsibility in attempting to lift the columns in dim or no light, and an inherent vulnerability to vandalism in leaving the columns on the street overnight. Although the traditional Roman workday was based on daylighting, work at the building site or on the transport avenues was unlikely simply to be halted by sunset. Material carts still clattered along the streets, and shippers and receivers guided the process. Some of the on-site tasks may have been carried out at night, but the absence of a pervasive light source would have severely limited the masons, laborers, and decorative workers.[264] As the work advanced, and the tasks required a resounding structural reliability, accurate work performed in daylight must have been at an absolute premium. In addition to daylight and a consistent labor force, the construction process demanded one other necessity from the site: unfettered access. The entire area of construction would have been effectively closed to through-traffic not associated with the project, as imperial assembly and manufacture always took the highest precedent in street use.

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[264] Columella *RR* 11.2.90-91 suggests that Roman agricultural workers find remedial tasks that may be done in artificial light during the shorter winter days. However, agricultural work hardly held the dangers inherent in large material maneuvering, or addressed the problems created by haphazardly mixing the wrong proportion of water to lime in concrete production. Also, as addressed earlier, construction events were probably mostly limited to non-winter months, when the days were longer and allowed for 12 hours of sunshine to work with.

Due to the size and speed of Maxentius' projects, the builders probably closed off entire sections of the city to accommodate construction traffic, which included roads leading from the Emporium or other inventory areas such as brickworks and lime kilns. The extent to which the general public engaged in spectatorship of on-site construction is unknown, but several ancient depictions of work sites indicate there was at least a passing interest and appreciation of workaday tasks. The "spectacular" was indeed rooted in the transporting and hoisting aloft of monolithic columns. Appropriately, the spectacle was enhanced at points of great difficulty and perceived peril along the multifarious course. In certain cases, the routing itself provided the danger. There are many aspects of material transport in the city that would require meticulous attention by the planners, including the arranging of the route through the busy Roman thoroughfares.[265] Public use had to be balanced with private commercial use, even in times with no construction traffic. A narrow, roughly-paved, dense street was suitable for the normal market day, but needed to be cleared of overhangs and other obstructions during times of large-scale construction, which possibly meant that storefronts and homes were not suitably accessible during a great deal of the day.[266] The most efficient method would be to completely empty the entire width of the road, but this would be very difficult in practice.

During isolated instances of heavy material transport, the Roman streets were prepared by affixing pulley mechanisms or capstans, and covering the stone surface with log rollers or even sand to change the friction quotient of the pavers. This is an interesting instance of the living city protecting itself from damage, or even "lubricating" its arteries. Sometimes installed

[265] For Roman street traffic and the character of the Roman via, see Poehler 2003 and Van Tilburg 2007.

[266] This is an assumption based on the length of large-scale material oxcart trains, and also the number of oxcarts with standard building materials like brick, timber, lime and even water that needed to traverse the same route repeatedly during the construction period. Other efforts to curb urban street traffic are logged in Suetonius *Claudius* 25.2 and *Historia Augusta*, *Marcus Antoninus* 23.8, where the emperor strictly forbade anyone to 'ride a horse or drive a vehicle' in any Italian city.

capstans and extant architectural features like porch columns were used to slow wagons with ropes during downhill travel.[267] In the case where gravity could not be relied upon to slowly lower large payloads down inclines, the streets would instead be subjected to scuffing and damage by the hooves of hundreds of oxen.[268] The intact streets of Pompeii bear witness to centuries of continuous wear, and display surface damage exerted by hooved traffic and purpose-cut ruts for oxcart transport.[269] As a result of this damage, the Pompeiian Forum was known to be closed to wheeled traffic, as evidenced by the large stones placed at each ingress and egress point to the central porticoed quarter.

Roman streets held many impediments to reliable wheeled traffic, including the large and sometimes protruding crosswalk stones at intersections, damaged surface stones, and other discarded or waste materials clogging the ability to maneuver a straight path. Martial records his experience of construction traffic in the first century, "the pavement [is] dirty with footsteps never dry, while it is scarcely possible to get clear of the long train of mules, and the blocks of marble which you see dragged along by a multitude of ropes." [270] Thus, part of the planning for an itinerary through any Roman city must include a widespread program of uncluttering the route. This may have been carried out in combination with a strict curriculum of recording both straightforward and problem areas for transport. As material transport was not novel to the city of Rome, there were set precedents to be followed and expectations to be met.

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[267] Methods of readying the street discussed by Favro in Laurence and Newsome 2011, p340.

[268] Bernard 2013, p108 mentions the significant risk undertaken by moving materials on the sometimes steep inclines of Rome's hills. This circumstance was also affected by other impediments along the route, like fire or falling buildings/roofs, the miscalculation of size/scale of materials, improper securing of loads, incorrect clearing of streets, and other scheduled events that needed to be removed or rerouted. The necessity for multiple yoking to pull even the smaller architectural blocks must have added to the difficulties.

[269] See Poehler 2003 for a study of cart ruts in Pompeii.

[270] Mart. *De. Spect*. 5.22.

The clearing of streets along the route meant that storefronts and homes would not be accessible during a great deal of the workday. It also meant that building façades and corners were not completely safe from damage, especially in crucial corridors, junctures, and bottleneck points. A massive monolithic column, or other construction material with precarious dimension or substantial heft, could easily destroy the wall or balcony of an apartment block or cause other collateral damage in the city.[271] Although the procession of marble had the power to dictate its route, the character of the buildings along the route made a huge impact in the difficulties of transport. Sharp corners and narrow corridors had the power to affect the routing of the parade, and sometimes necessitated a change in the entire organization to avoid altering the present symbiosis. The basilica's columns likely avoided known impediments by traversing areas like the wide "Via Triumphalis," the well-traveled support road along the Tiber, and the ample berths afforded by the Forum Boarium and the Circus Maximus.

As every payload approached the central Forum Romanum from either side, the road would successively narrow, and the crews would encounter a known bottleneck. Each material train approached the site via the "Via Sacra," and as the oxen and their drovers slowly converged on a narrower point, they found each step to be more constricted than the last. The difficulty in traveling the last few meters to the building site steadily increased, and tested the mettle of the planning staffs and laborers alike. At this point, the directive may also have been impeded by other construction traffic, including small material wagons darting to and from the staging areas lying just offsite. Depending on the successful nature of the entire trip, the payloads probably arrived at the site later in the evening, when the crews' patience and endurance was wearing thin.

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[271] Delaine 1997, pp99-100, DeLaine quotes both Tibullus *Vit*. 2.3.43-44 and Juvenal *Sat.* 3.257-61 concerning the disruption created by heavy wagons moving through the streets of Rome. Laws concerning the limiting of overhanging balconies (sometimes to eliminate the blocking of neighbor's daylight) existed in Rome as well, as attested to in *Cod. Theod.*. 8.10.11-12 and Justinian *Dig.* 488.2.14.

All of these variables contributed to the character of the bottleneck, increased the amount of things that could go wrong, and enhanced the inherent watchability of the proceedings.

In this case, any seating or standing areas may have been very small and haphazardly distributed about the area, owing to the confined space between the Colosseum valley, Palatine Hill, and central Forum. The best views of the action were held at a premium, and a loose choreographing of the crowd was undoubtedly necessary for safety reasons. Spectators might randomly accumulate at pivot points for the column and oxen train, as well as any bottleneck point when the monolith needed to be raised or lowered (see Figure 25). Such an episode of spectatorship is described by Horace, "a builder in heat hurries along with his mules and porters:

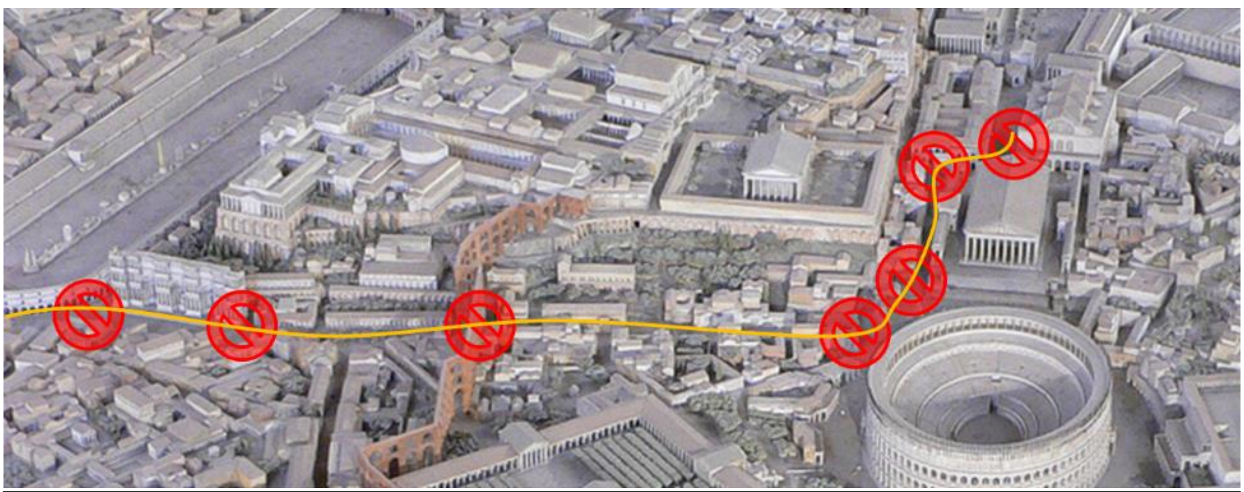

Figure 25: Detail of *Plastico di Roma Imperiale* model (I. Gismondi: Museo della Civiltà Romana, 1933-1955). Orange indicates the likely route taken from the Circus Maximus through the Colosseum Valley to the Basilica of Maxentius. Red indicates likely bottlenecks for oxcart travel, including 90-degree turns, narrow berths through arches, points where many building materials merge together, and other points where the large-scale cargo had to be further secured or modified.

the crane whirls aloft at one time a stone, at another a great piece of timber."[272] As it was, the *cavea* of the Circus Maximus, the surrounding buildings of the Forum Boarium, and the sloping

[272] Hor. *Ep*. 2.2.72-80.

hillsides facing the straight and long "Via Triumphalis" afforded suitable areas for onlookers curious to watch the column movement.

Several scholars believe that any suitable staircase on the front of temples, porticoes, and other buildings facing the action were crowded with spectators.[273] Other viewers might even have stood in the outer arcades of the Colosseum to witness the turning of the columns, or near the Temple of Venus and Rome to watch the raising of the columns. In these locations, the engineering challenges are magnified, and the spectatorship is escalated. Although there were many slight turns along the meandering processional route, the primary impediment was negotiating a ninety-degree turn in the Colosseum Valley. A famous task on a similar scale has been described in the *Historia Augusta*,

> "Hadrian raised the Colossus [of Nero] and, keeping it in an upright position, moved it away from the place in which the Temple of Rome is now, though its weight was so vast that he had to furnish for the work as many as twenty-four elephants."[274]

A task like this, even without the aid of gargantuan exotic animals, undoubtedly drew the interest of a large crowd of spectators. As Maxentius was simultaneously renovating the Temple of Venus and Rome adjacent to the Basilica of Maxentius, it is feasible that the entire massive podium of the temple, and the rest of the Velian spur between the Colosseum Valley and the building site might have been strewn with onlookers awaiting the climactic event of the marble parade.

Before the columns approached the basilica, basic preparations had to be made to precipitate their arrival and placement on site. All of the support scaffolding, vestiges of

[273] Favro in Laurence and Newsome 2011, p346, Taylor 2003, pp4-5, DeLaine 1997, pp99-100, and Goldberg "Plautus on the Palatine," *The Journal of Roman Studies* 88 (1998): 1–20.

[274] Ael. *Sp. Had.* 19.12. Admittedly, the writer of the Historia Augusta is notoriously unreliable. The hyperbole of such writing adds to the expected spectacle of such heroic acts of engineering, and strengthens the idea of watchability.

demolition and foundation work, and remnants of building materials and equipment must have been cleared out of the central area. Eventually the formwork for the central vault would cover the entire floor of the basilica in an intricate web of scaffolding, but in order to maneuver the columns, these tasks had to be moved to later phases of construction. Implements like cranes, lift towers, and large-scale hinge mechanisms were built and made ready. Ramps were placed on the southern side of the site, to bridge the height difference between the "Via Sacra" and the basilica floor. One-third of the basilica's bulk awaited the first four columns, but at this point the visible procession of the Proconnesian monoliths must have functioned as a rallying cry for overall construction. It was absolutely necessary for two-thirds of the structure to be open at the time of the columns' arrival, in order to pivot the columns, and either temporarily store them or ready them for erection.

The immediately neighboring area was topographically dense, and the Basilica of Maxentius was hemmed in by the Temple of Venus and Rome, Temple of Romulus, Porticus Margaritaria, and Forum Pacis, which severely limited the possible areas for maneuvering the columns outside of the basilica. Thus they were most likely brought directly across the threshold of the southern wall and stationed inside the spacious incomplete basilica. The vast length of the oxcart train suggests that the entire procession continued past the building, until the column itself had reached the area of the southern basilica wall. Only then could the columns be rolled or hoisted up the ramps to the floor. This process must have relied on pulleys or rollers, given the constricted area and inability to employ the entirety of the oxcart train. Several yoked oxen pairs may have aided in this penultimate movement of the columns, but the overall operation must have been scaled back significantly.

The walls and piers of the northern side aisle vaults were then prepared for the placement of the first four columns. The successful erection of these primary columns, even without the existence of the central vaulting, essentially dictated the height of the entire structure. A system of trial and error had been employed in prior Roman construction projects, and success was paramount. If the initial venture failed, the immediate outcome would resemble Taylor's theory concerning the inability of Hadrian's Pantheon to receive and erect 15-meter columns. Construction plans would then be adjusted, and new columns located or requisitioned, halting the entire process for months. This outcome may indicate that columns contemporaneously located inside the city of Rome would be highly desired, which lends credence to Taylor's theory that the columns for the Basilica of Maxentius were spoliated from the Temple of Serapis. Given the difficulty of arranging eight successive oxcart trains carrying massive marbles, any failure in erecting the columns onsite could derail the entire project. It is with respect to the severity of this circumstance that the eight columns were brought to the basilica.

As each of the first four columns for the northern aisle arrived at the building site, it was either raised directly into place or briefly stored with its compatriots until the lifting apparatus could be installed.[275] The former possibility afforded four unique efforts to reward the patience of any onlookers, and the latter might be staged as a continuous raising effort carried out over days or weeks. An interesting example of the pomp and circumstance associated with raising large marbles is recorded at the Temple of Artemis in Sardis, where an inscription on the column

[275] Although the columns likely arrived on site horizontally, they may have been temporarily stored in the Basilica either horizontally or vertically. Presumably it would have been easier to upright all of the columns at once, in order to employ the same mechanisms and workforce over the course of several days. However, it would require less floor space to upright the columns when they arrived, and store them vertically. Each column would thus only have a 2-meter footprint. If the columns were stored vertically, the builders would be free to go about their other building tasks, including brickwork and vaulting, and install scaffolding around the shafts. This would probably allow for a more malleable working schedule.

itself promptly states “of all [the columns] I am the first to rise.”[276] This chore may have taken weeks in itself, as evidenced by the aforementioned record of pre-industrial obelisk-hoisting in St. Peter’s square in the 1500s. The Roman solutions to this problem including deploying wood rollers, pulley systems, lifting towers, cranes, and other ingenious contraptions.[277] The process moved at incredibly slow speeds, and relied on the smallest of incremental changes to adjust the trajectory of the column.

The raising of the basilica’s columns employed a variety of equipment, including cranes and other simple machines. In Vitruvius’ tenth book on machines, the author describes many cranes, and elaborates that these machines are used for hoisting heavy loads during “the completion of temples and public works,” and also for loading and unloading ships.[278] He mentions that some of these machines are set upright in a stationary position, while some have revolving booms. Vitruvius also describes an instrument of laminated wood and supporting cords that resembles a fulcrum lever mechanism. Capstans at the ground level would feed the cords through pulleys to effectively tension the wood beams, and pull the column from a lying horizontal position to its vertical standing position. This type of instrument would require a horizontal area on the floor of the Basilica of at least two-to-three times the height of each column to successfully operate (see Figure 26).

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[276] Buckler and Robinson *Sardis VII: Greek and Latin Inscriptions. Part 1: Seasons 1910-1914*, Leiden: 1932, pp143-144 (no. 181), and Yegul, Bolgil, and Foss *The Bath-Gymnasium Complex at Sardis*, Cambridge: Harvard University Press, 1986, p70.

[277] See Adam 1999, pp43-51 for the process of lifting a column; see also Lancaster 1999, pp426-432 for speculation on lifting mechanisms. As described below, the Romans likely used a combination of mechanisms at the Basilica of Maxentius, including the up-righting device described by Vitruvius *De. Arch*. 10.2.2 and illuminated in Adam 1999, p47 (figure 98).

[278] Vitruvius *De. Arch*. 10.2.1-4.

Large wooden cranes, which were spectacular examples of Roman ingenuity in themselves, would then lift the column into its place on each podium.[279] Vitruvius illuminates

Figure 26: Superimposition of 3D model of lifting machine by the author after the descriptions of Vitruvius and the drawing by J.-P. Adam into a GoogleEarth framework with 3D building of Basilica of Maxentius activated. Map data: Google, Landsat.

this type of pulley-based machinery, which was operated by *mechanicos*, or many workers, as opposed to one skilled workman. Depending on the size of the loads, these cranes employed single or double boom arms, with *trispastos* or *pentaspastos* tackle to raise and lower the load. The largest of loads would require reduction gear, including the use of capstans to tensions the boom arms. The difficult and unwieldy loads would be hoisted by treadmill cranes, like those pictured in the Haterii Relief. These cranes have been depicted with up to eight workers inside the bowels of the treadmill, which provide the necessary power to manipulate the loads. The operation of a single machine might require dozens of teams, but even more impressive is the

[279] Treadmill cranes are also described in Vitruvius *De. Arch*. 10.2.1-4, and championed by Adam 1999 and Taylor 2003.

Roman technique of using these machines in tandem to achieve a singular purpose; in this case to erect a 15-meter column.

The combination of the two machines would require an area over half the size of a football field. This may have been even larger depending on the desired locations for cords and capstans, and the necessary safety perimeter. For a 15-meter column, the engineers must have employed at least a 25-meter boom-arm treadmill crane. In order for the workers to raise the contraption and tether all the guide-wires in a circular fashion, these figures would yield an area of between 2000-2500 square meters (See Figure 27).[280] The fulcrum column-raising machine also takes up almost 750 square meters. If the area of the two implements is considered together with the various material staging areas at the Basilica and the impediment of the already-erected northern side aisle, the severity of this particular problem comes steadily into focus.

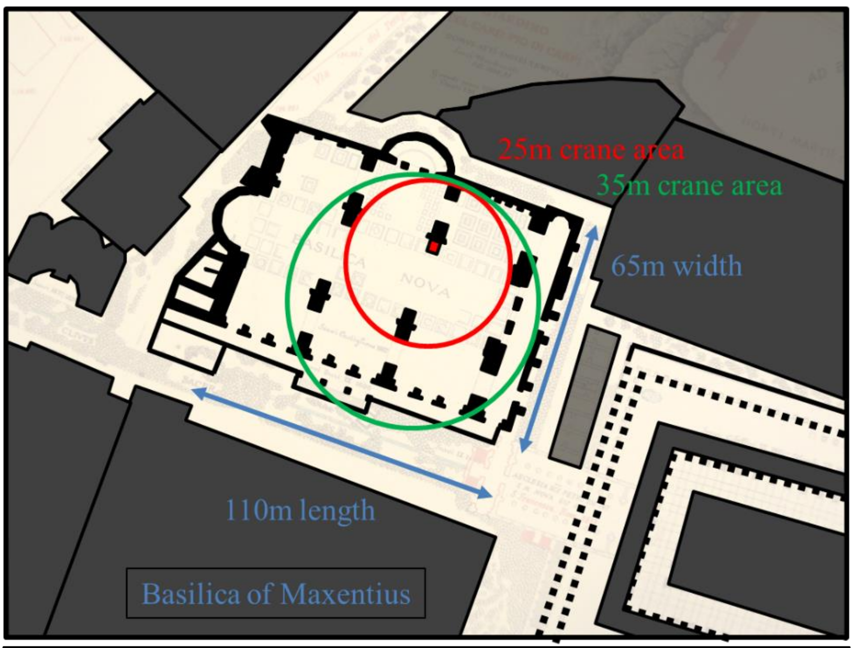

Figure 27: Diagram of Basilica of Maxentius worksite, with depictions of areas necessary to stage boom-arm treadmill cranes. A single column location along the north vault wall is highlighted in red.

The 4th-century historian Ammianus Marcellinus describes the

[280] A 25-meter crane, considering a full range of movement backward and forward, would require almost nearly 50 meters of space in one direction. Additions like capstans and guide ropes would necessitate a circular area to control the crane properly, or at least 2000 meters in a standard area calculation. A larger crane of up to 35 meters, with appropriately longer guide ropes, would increase the area significantly.

raising of such a monolith in Rome during the time of the Emperor Constantius II:

> "now there remained only the raising, which it was thought could be accomplished only with great difficulty, perhaps not at all. But it was done in the following manner: to tall beams which were brought and raised on end like a grove of derricks, were fastened long and heavy ropes in the likeness of a manifold web to hide the sky with their excessive numbers. To these were attached that veritable mountain, and it was gradually drawn up on high through the empty air, and after hanging for a long time, while many thousand men turned wheels resembling millstones, it was finally placed in the middle of the circus."[281]

Each successful engineering feat thus operated as a commemoration of the building's impending completion, and functioned as a testament to the power of the emperor's construction industry. The "Via Triumphalis" and the "Via Sacra" provided a successful venue for showcasing the marble monoliths as they moved into their spot in a politically-charged building project. The route of the procession surely presented problems of transport, but also proffered a grand showcase for the solution of these problems.

In the tradition of displaying spoils of war, the oxcart and marble procession depicted the pageantry and spectacle of a triumph. The slow and deliberate movement of the marble column past the Circus Maximus and the Colosseum, up the sacred way, and into place at the Basilica of Maxentius loosely resembles the path of the *triumphator*. The penultimate act is the erection of the column, which takes the place of the ritual sacrifice. The raising acted as the climax of the procession, and delivered a final herculean feat of ingenuity and significance to the gawking spectators (see Figure 28). The people of Rome likely witnessed the heroic hoisting of these monoliths into place, but missed the equally inspiring year-long odyssey across the Mediterranean. It is a small wonder that such magnificent pieces of stone might arrive at the basilica unfettered by their countless times loaded and unloaded, raised and lowered, shipped and rolled, pushed and pulled. That the columns seamlessly unify with the myriad building materials

[281] Ammianus Marcellinus *Res Gestae* 17.4.14-15.

utilized at the basilica is a testament to the entire contextual relationship of large-scale Roman building. Designers, engineers, planners, masons, and drovers work tirelessly in cooperation with each other to keep a city functioning while its construction industry displays a relentlessly precise system of logistical planning. The spectacle inherent in celebrating the arrival and erection of large building materials serves as a lens in which the perfectly symbiotic relationship between the construction process and the city of Rome is magnified and interrogated.

Figure 28: Rendering of a treadmill crane by the author after the Haterii Relief; in this case represented for construction in the north end of the Roman Forum. Image of Digital Roman Forum used courtesy of UCLA ETC.

4. Symbiosis Employed: Construction of the Basilica of Maxentius

4.1. Defining the combinatory nature of the basilica's site

Every infrastructural artery employed in the process of construction necessarily culminates at the building site. Upon arrival at this terminus, all building components great or small had taken advantage of the multi-faceted system of construction processes superimposed on the city, and now awaited their ultimate incorporation into the overall design. Massive monolithic columns, notable for their difficult height, weight, and volume, joined an entirely new choreography of disparate construction elements on site. Large-scale concrete vaulted construction employed a variety of materials and laborers, all accompanied by individual requirements and exigencies. The cacophonic multitude of constituents required a seamless orchestration to ensure successful completion.

The fact that the Basilica of Maxentius was finished in less than six years leads to the conclusion that the building teams worked at an incredibly versatile pace, and held fast to an imposed time constraint. Here, architectural energetics analysis again helps elucidate the daunting task of providing materials and organization for the building site. If the size of the structure and complement of building materials are proportional to about half of that documented at the Colosseum, then the basilica may have relied on over 150 to 200 oxcarts full of materials each workday to the center of the city.[282] The Maxentian project was confined to a comparatively tight space in the city center of Rome, and was carried out in tandem with up to five simultaneous projects.[283] The only tangible method of completing such a task is a sustained

[282] See the studies on the Colosseum by Taylor 2003, pp134-173 and Homer-Dixon 2006, pp31-56.

[283] Giavarini 2005, p21.

reliance on the network of infrastructure and site organization, which functioned in both a self-determining and co-dependent way to produce results indicative of an organismic system.[284]

The Basilica of Maxentius worksite was complicated by several internal factors, and compromised externally from several different directions. In placing the initial building footprint on a spur of the Velian, the designers had to negotiate existing buildings and navigate difficult contours, all within a space that was barely big enough for its substantial heft. The basilica was also planned as a cog in the Maxentian building machine, and would function in a largely combinatory workspace with several other buildings. Each of the Maxentian building projects had their own requirements, but the overall unified character of the brick facings, concrete vaults, monolithic columns, and marble revetments predicted a largely united material cache and accompanying task force that linked the multifaceted building chain together throughout the city. It is important to note the possibilities of fulfilling several constituent orders at once, and routing many material chains through equivalent passages and gateways throughout the city. Just one Roman building project inherently stressed the city's resources considerably, but a plan for several similar structures in a centralized area would eliminate the successive stresses of each consequent project.

During the period of Maxentian building, the city of Rome thus exerts itself as the host organism in an efficient symbiotic relationship. In addition to providing the transport avenues and regulating street traffic, the city and its mechanisms direct and control several aspects

[284] An interesting corollary for how construction, materials, and organization are handled in a modern context is provided by Building Information Modeling (BIM). According to the US National BIM Standard Project Committee, BIM is defined as "an overall digital representation of physical and functional characteristics of a facility; it is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle, defined as existing from earliest conception to demolition" (nationalbimstandard.org). The BIM concept has existed since the 1970s, and was popularized in the paper Van Nederveen and Tolman "Modelling Multiple Views on Buildings" *Automation in Construction* 1, no.3 (1992): 215-224, and later codified as 'Building Information Modeling' by software platforms Autodesk and Vectorworks. BIM serves as a modern digital platform that mirrors the investigations set forth here combining site catchment and architectural energetics analysis to explain the construction process and project management in an ancient setting.

governing successful use of infrastructural networks and labor. Rome's civic governance by urban praetors and *collegia* dictated the terms of labor supply. The interesting mix of dense boroughs throughout Rome created a local pride, which resulted in a controlled flow of goods and services, a neighborhood management of street traffic, and even the dictation of pathways used in for spectacular construction transport. Roman city law allowed for centralized spaces like the Forum Boarium and Forum Romanum to be opened up for transport, storage, and staging. The combination of several efforts at once would allow use of all the infrastructural processes of construction, and permit an overall building boom in the city. The commercial, industrial, social, and political ramifications of such a boom are exceedingly difficult to quantify, but notable for their impending impact on the entire architectural character of late Imperial Rome. In order to quickly implement the many Maxentian projects in the capital, the architects and planners were likely abetted by the efficient deployment of a combinatory system of worksites.

4.2. Architects and contractors lay out the master plan

The Roman construction process required an interspersed network of agents, contracts, teams, and leadership roles, and left exceptionally little in the way of literary testimony and epigraphic evidence.[285] The dearth of evidence is so severe that in his study of Roman building, Rabun Taylor warned that it would be 'unprofitable' to even attempt to determine the specific roles and duties of the architect (*architectus*), master builder (*fabri*), or building contractor (*structor*) at an individual project.[286] Vitruvius himself recognized several possible arrangements

[285] For this lacunae, see supra. note 94.

[286] Taylor 2003, p13. The current study will outline the specified duties at a construction project, without necessarily assigning the tasks to a specific person or persons, unless known by evidence. As mentioned by Taylor, the *lex Puteolana* from 105 BCE is probably the most complete examples of a building contract specifying roles and duties as they applied to a small building project in Puteoli. However, as this document is 400 years removed from the Late Empire, its veracity would be questioned. In truth, it would not be possible in this study to outline every construction

between the architect and the supplementary roles of client and contractor.[287] Indeed, without extant documentation at the Basilica of Maxentius, it is difficult even to assign an architect, or ascertain who had a hand in positing the final design plans. Only a few architects are known from antiquity, as building inscriptions seldom give any information on the generative process or the communication networks in play.[288] Architects worked in several different capacities, according to the size and scope of the project, involvement of the patron, and especially the degree of training.[289] Specifically, the architect was the chief designer of the building, and the primary allocator of building costs.[290]

For massive imperial projects like the Basilica of Maxentius with complicated scheduling and an intimidating measure of raw materials, the architect delegated most of the tasks to a hierarchy of authority, including several other contractors and possibly engineers.[291] This hierarchy was probably governed by a ranking system, wherein professional builders of

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task or contract rendered at the Basilica of Maxentius, much less in the overall building program carried out in Rome circa 306-312 CE.

[287] Vitruvius *De. Arch*. 1.1.10.

[288] The difference in roles of the ancient architect and modern architect are important to note at this point. In Rome, the architect must be thought of as a master craftsman employed for the practical purpose of erecting a structure. Taylor 2003, pp9-14 mentions that credit for architectural achievement went directly to the patron, with the architect/builder relegated to “a facilitator.” Apollodorus of Damascus was among the very few known Roman architects, but this may owe to the fact that the architect famously and disrespectfully confronted his patron Hadrian about “drawing his pumpkin domes,” and was promptly executed for it. The information about architects, contractors, and builders is noted from hundreds of funerary inscriptions memorializing the tradesmen, including the aforementioned relief of the Haterii. Architects did not enjoy an elevated class status until possibly the Renaissance era 1500 years into the future. As summarized in Sykes ed. *Constructing a New Agenda: Architectural Theory 1993-2009*, New York: Princeton Architectural Press, 2010, p25, the concept of the “starchitect,” in which an architect is lauded for his or her genius creations, internationally employed for glamorous commissions, engendered to build an iconic brand of their own, and encouraged to advance the methods and theories of architecture rather than fill a spot of land with a building, is overwhelmingly modern. For additional evidence in the representation of craftsmen in the trades, see Senseney *The Art of Building in the Classical World: Vision, Craftsmanship, and Linear Perspective in Greek and Roman Architecture*, Cambridge: Cambridge University Press, 2011.

[289] Taylor 2003, p13-14; for role of the architect in the construction process, consult Anderson *Roman Architecture and Society*, Baltimore: Johns Hopkins University Press, 1997, pp3-118, and Gros *Architecture et societe a Rome et en Italie centro-meriodionale aux deux derniers siecles de la Republique*, Brussels: Latomus, 1978.

[290] Vitruvius *De. Arch*. 1.2.8; Vitruvius cites allocation among his basic components of architecture, which involves first and foremost the budgeting of costs, even for the larger-scale projects.

[291] Taylor 2003, p14.

appropriate status would meet regularly with contacts in the department of public works, or other overseers of material procurement and requisitioning, contract management, and most importantly, the treasury for the project.[292] The immediate situation surrounding the ascension of Maxentius likely convoluted the direct procedures for building, but an appropriate Late Imperial-era organization was likely employed.[293] As a result of his swift and effective coup, Maxentius was probably allied with most of the larger departmental entities in Rome, including the urban prefect (*praefectus urbi*), and certainly controlled the monetary coffers.[294] The project architect and the urban prefect, both of whom were likely appointed directly by Maxentius, controlled the processes of requisitioning materials and labor, drawing up contracts, and paying the bills.[295] The basilica's planners worked in tandem with the construction guild (*collegia)* to solidify all building strategies and acquire the necessary dispensations for area use. The fact that a large construction project like the Basilica of Maxentius, in combination with the rest of Maxentius' wide-ranging building program, was mostly completed in six years is astonishing, and suggests that an extremely efficient building *collegia* existed in the city and was working directly for the

[292] Ibid.

[293] It is nearly impossible to ascertain the state of the office of public works at this time, as it had recently been decentralized by Diocletian and reapportioned by Maxentius. However, for the purposes of this study, the previous pre-Diocletianic set-up will be used as a reference.

[294] Lancaster 2005, p21; Lancaster cites Chastagnol *La prefecture urbaine a Rome sous le Bas-Empire*, Paris: Presses Universitaires de France, 1960, pp27-30, 348-349 and Ward-Perkins 1984, pp38-48, who claim that within the Tetrarchic scheme, the supply of building materials to Rome was controlled by the urban praefect (*praefectus urbi*), whose jurisdiction extended to a one-hundred-mile radius outside the city (which would include most of the material manufacturers). Maxentius was known to have disposed of the prior urban praefect, and probably installed his own. In either regard, Maxentius most likely controlled the supply of materials for his projects.

[295] Lactantius *De mort. pers.* 7.8-10, Williams *Diocletian and the Roman Recovery*, New York: Methuen, 1985 pp134-135, Jones *The Later Roman Empire 284-602: A Social, Economic, and Administrative Survey*, Oxford: Blackwell, 1964, pp838-840, 858, Lancaster 2005, p21; the building contract bids (*redemptores*) of the early Empire had been replaced by a system in which labor for building projects was requisitioned by the state as a means of tax-collecting through the *collegia*. With regards to the Maxentian era, none of the architects, builders, contractors, praefects, or the exact makeup of the building *collegia* is known for the period of time elapsed between Diocletian and Constantine.

emperor. Thus, an unknown but capable series of construction teams were dispatched by the chief architect to begin building, preparing, or transporting materials throughout the city.

Ancient Roman architects were able to categorically communicate their designs to builders or laborers in visual format, as indicated by several preserved examples of ground plans drawn or etched into stone.[296] However, these mostly-commemorative examples of plans leave no evidence of true working drawings, sections, or elevations, which has led scholars to believe that architects mostly transmitted instructions verbally to builders, or relied on traditional practices for prompt completion of tasks (see Figure 29).[297] The workers benefited immensely from this tacit transmission of building technique from one project to another, as the basilica most likely employed the very same designers and engineers that had built the vaults of the Baths of Diocletian only a few years prior. Although the scale and proportion of the central vaulting would be unlike anything attempted in Rome, the builders were already tested and drilled in production and assembly, and familiar with every raw material that would contribute to the final structure.[298] However, the work carried out by laborers to gather

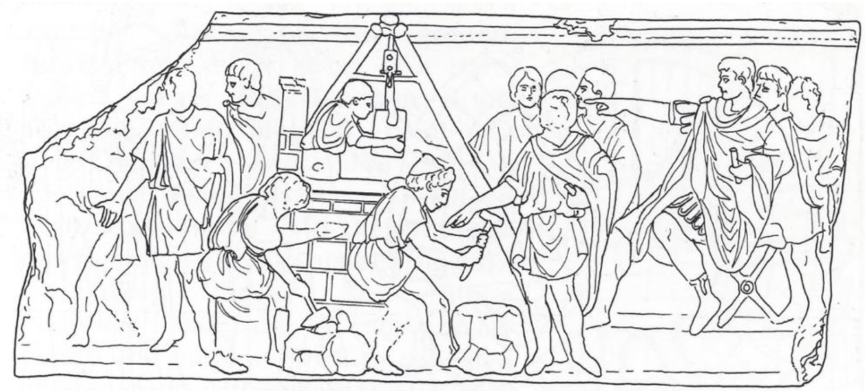

Figure 29: Scene of a building site on a relief found at Terracina. Drawing by Adam after relief in National Museum, Rome. Image reproduced from Adam 1999 (Fig. 90, p45).

[296] DeLaine 1997, p66; for the preserved plans, consult von Hesberg "Romische Grundrissplane auf Marmor," *Bauplanung und Bautheorie der Antike, Diskussionen zur Archaologischen Bauforschung* 4 (1984): 120-133.

[297] DeLaine 1997, p66; also Gros "Le role de la *scaenographia* dans les projets architectraux du debut de l'empire romain," *Le dessin d' architecture dans les sociétés antiques* (Actes de Colloque de Strasbourg) 1948: 247-250.

and assemble supplies was an entirely remedial task compared to the successful estimation of total materials by the construction planner.

Total material amounts and cost estimates are difficult to determine at most Roman building projects, owing to rudimentary calculation methods, anticipated cost overruns, and frequent materials shortage, surplus, and even theft.[299] Roman architects used simple principles of geometry and traditional approximations to estimate materials, but there is no explicit epigraphic evidence of these calculations at any known construction projects.[300] The theoretical basis for understanding the behavior of concrete vaults had been laid by Archimedes in the 3rd century BCE, and interpreted again by Heron of Alexandria in the 1st century CE, but neither

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[298] The existence of local master builders, contractors, and laborers is inferred from the very recent constructions of *thermae*-type halls in Rome, as mentioned above. However, this may not always be the case, as Taylor 2003, p17 remarks that reasonable estimates of materials and labor were difficult to come by, as large Imperial projects usually specified expensive materials and craftsmen pulled from considerable distances. In truth, the very existence of craftsmen in Rome who knew the intricacies of building frigidarium vaults from their prior work at the Baths of Diocletian may have been a consideration in the change of the basilica building typology, from two-story trussed colonnaded hall to frigidarium-vaulted hall.

[299] Taylor 2003, p18 notes the study Duncan-Jones *The Economy of the Roman Empire*, Cambridge: Cambridge University Press, 1974, pp75-80, 89-99, which cites several inscriptions from Roman Africa that record initial sums promised for buildings, and additional expenses that were subsequently incurred. Some of the cost overrun may be attributable to the use (or inferred use from the inscription) of round numbers in estimating initial sums, although it is not known whether these round numbers, like 400,000 *sestertii* for a theater at Calama, were indicative of a lack of precision in estimates. Overall security and protection from theft remains a constant issue on construction sites worldwide. A corollary for modern site security is provided by Carney *Securing the Outdoor Construction Site: Strategy, Prevention, and Mitigation*, Amsterdam: Butterworth-Heinemann, 2016; important sections include "The Impact of Construction Site Theft" pp1-10, and "Theft of Materials" pp36-37. Carney introduces his text as follows, "Theft from construction sites is probably older than the pyramids in Egypt." This statement, although broad, addresses the idea that construction sites hold many extremely valuable materials, and thievery has likely abounded as long as sites lay unsecured. There is evidence of laws created to address construction site security, but most seem to only tangentially consider building tasks or materials. An example is the "Permanent Edict of the Urban Praetor" c. 129 CE, where provision 257c is among a series of interdicts protecting places where "new work will be built" from protesters or other threats (Johnson, Coleman-Norton, and Bourne *Ancient Roman statutes: a translation with introduction, commentary, glossary, and index*, Austin: University of Texas Press, 1961, p194). In the following centuries, theft and unauthorized spoliation remained issues in Rome. Glendinning *The Conservation Movement: A History of Architectural Preservation, Antiquity to Modernity*, London: Routledge, 2013, pp18-19 notes that in 500 CE, Theodoric appointed special magistrates to address the problem of thievery (especially at night), and moved statues and other materials to the centrally-secured Forum to protect them from theft.

[300] Lancaster 2005, pp10-11 notes that Heron of Alexandria wrote a treatise in the 1st century CE called *On Vaulting* (*Camarika*) that does not survive. In it, he is presumed to have written about more precise calculations for vaulting, including geometry, balancing of masses, and relationship between bodies. Lancaster notes that there is no explicit evidence that the Romans ever developed the means to calculate actual thrust forces.

theoretician posited any practical application of this theory to amount of building materials. In Rome, the planning and execution of such structures was more likely based on a system of experimentation and trial-and-error, which culminated in many successful concrete-vaulted structures in Rome despite the admitted riskiness of relying on such methods.[301]

Labor commitment, energy required, and overall construction time also proved to be difficult to estimate near the inception point of building tasks, as this process required several discussions between the patron of the project, the architect, and several of the master builders and craftsmen.[302] During large-scale concrete vaulted construction, each building task was increasingly more contingent on the completion of the preceding task, which created a sequencing predicament.[303] The vaults were only able to be constructed after the walls were built, which was contingent on the foundations, which in turn relied on demolition and excavation. Each step of the process was engrained with its own schedule of materials delivery, amount and type of building crew, and overall completion time. It would be a colossal misuse of resources if material delivery were timed incorrectly, or if certain crews were not specialized for a task.

Scheduling was also integral to the process because of impending area shutdowns. Any large-scale project in the city center would need the appropriate transport avenues and material staging areas to be widely available, which meant shutting down the pedestrian and commercial access to said areas. Shutdowns inevitably led to lost revenue in other disciplines, and necessitated precise planning and execution by the building teams. The apportioning of site

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[301] Lancaster 2005, pp5-10.

[302] Taylor 2003, p17-18; Taylor notes that labor cost and amount was probably figured in direct proportion to materials needed, and also hired in direct correlation with the availability of specialized task workers. Also, although labor seems to be as inelastic as material estimates, overall construction time seemed to be the most difficult, as it was based on “room for doubt and improvement.”

[303] Noted by Taylor 2003, p18.

access would prove just as valuable as the coordinating of shutdowns, as builders required unconditional access to discrete parts of the site in order to carry out the ordered construction tasks. Full access to the site was also pertinent early in the process because of the judicious aggregation of materials, creation of on-site workshops, collection of technology and tool emporiums, and prudent fabrication of construction implements.

4.3. Preparing and using construction implements, technology, and tools

During Roman construction, the complexity and durability of technology had to mirror the large-scale, multifaceted tests of engineering. Tools, tackle, binding elements, wood, metal, construction implements, and other support mechanisms were commonplace on site, and were integral to the successful and timely completion of tasks.[304] All men and machines were managed accordingly, and their tools made easily accessible.[305] Here, a mutually beneficial symbiotic relationship would dictate that the correct agent and tool for each job be distributed to the right place at the right time. For the length of the complicated Roman building process, workers, implements, and materials were positioned about the site, and divided into pragmatic sections that sped the job along. The principle job site was supplemented by myriad staging areas

[304] An interesting example of the importance of tools to the proper and virtuous completion of a task is provided in Lucretius *On the Nature of Things* 4.513-4.519, where the author compares faulty thought processes with the faulty use of tools when building a house, "in a building, if the original straight-edge is deformed, or if a faulty square departs from straight lines, or if a level is a trifle off in any part, the entire structure will necessarily be made imperfectly…thus your understanding of matters must be warped and faulty whenever it is produced from false senses."

[305] Much of the management of men and materials owed to the logistical expertise gained in the Roman military. Soldiers in military service are responsible for constructing much outside of the city or Rome, and have been notably represented doing so on the Columns of Trajan and Marcus Aurelius. Beckmann *The Column of Marcus Aurelius: The Genesis and Meaning of a Roman Imperial Monument*, Chapel Hill: University of North Carolina Press, 2011, pp158-163 identifies several construction and *adlocutio* scenes that abound on the column. For construction scenes on Trajan's Column, see Coulston "The architecture and construction scenes on Trajan's Column," in Henig ed. *Architecture and Architectural Sculpture in the Roman Empire*, Oxford: Oxford University Press, 1990: 39-50. For overview on tasks and organization of the Roman military, see Southern *The Roman Army: A Social and Institutional History*, Oxford: Oxford University Press, 2007, particularly "Organizational Structure," pp98-114 and "Doctrine and Strategy," pp171-185. Republican references to military construction can be found in Tacitus *Ann*. 2.14 and throughout Caesar *Bell. Gall*.

and spot workshops, some of which were located near the site and others strewn about the city. The amount of marble, brick, and other raw materials that were expected on site had to be efficiently organized, and the appropriate craftsmen had to be made aware of their location and timetable for arrival. Most of the ensuing construction tasks were necessarily simple and carried out by skilled masons, carpenters, and artisans. But some of the tasks, such as the raising of the columns, employed a variety of equipment, including cranes, lift towers, raising machines, and other implements. The combination of technical engineering knowledge and an efficient organizing framework was absolutely necessary to accomplish such a task.

On site, the majority of workers required basic tools for basic tasks, but other skilled craftsmen required far more complex technologies for specialized tasks. Measuring, marking, cutting, and joining remain the stalwarts of all building construction, and the Roman construction site was fully prepared and equipped for each basic task, even at very inception of the project. Architects in particular furnished their own tools, mainly because they were presumed to be extremely capable masters at their craft, and employed these tools early and often in the framework of construction.[306] Invariably, architects and even lesser

Figure 30: “Memento Mori” mosaic, depicting the libella tool. Pompeii, House-workshop I, 5, 2, triclinium (30 BCE – 14 CE). Museo archeologico nazionale di Napoli, Inv. 109982. Photo by author.

[306] Vitruvius *De. Arch.* 1.2-1.10 details the training of the architect and mastery of building elements during the Augustan era, admittedly before large-scale concrete-vaulted masonry work was common in the Later Empire. Further evidence that architects in particular were connected to, and even represented by their tools is provided by Cicero *Letters to His Brother Quintus* 3.1.1-3.1.2, “Diphilus, the architect, has erected columns that are neither perpendicular nor opposite each other. He will have to pull them down, of course. Eventually he will learn the use of the plumb-line and measuring tape.” In fact, Diodorus of Sicily *History* 4.76.4-4.76.6 records the story of Daedalus’

craftsmen became so linked to their tools that technical iconography became representative of the profession of building. The carpenter's square (*libella*) was such a useful implement in a variety of building tasks, like carpentry, engineering, and surveying, that it proliferates the grave markers of a variety of workmen, usually appearing with plumb-lines, hammers, compasses, or saws (see Figure 30).[307] Apart from a few interspersed funerary commemorations, the evidence for so-called "low technicians" is quite obfuscated, and the daily habits of medial laborers difficult to wholly understand.[308] Perhaps craftsmen affiliated with the various *collegia* were able to collect and centralize technical tools, but based on the pride exhibited in tools as a symbol of a trade, it is more likely that each individual workman maintained his own.[309] There is no evidence of a system of worksite "lockers" to store specific tools and implements, but it is very probable that such a set-up existed based on the sheer number of workers, the combined weight of tools and tackle, and the centrally located building site.[310] In addition to the carpenter's square, site technicians employed other tools for measuring and marking, which included plumb bobs, calipers, chalk lines, compasses, dividers, levels, and rulers.[311] Cutting and joining tools included

murdering of Talos because the rival architect/craftsman had discovered the carpenter's saw and circle-drawing tool, which would undoubtedly increase his fame. Again, the tool is inexorably linked with the architect.

[307] Cuomo 2007, pp84-85, the carpenter's square was linked with architecture and carpentry as early as New Kingdom Egypt, and Cuomo sites several examples of its widespread symbolism in Rome, including a grave stele from Reggio Emilia, a funerary relief from Verona, and a sarcophagus from Arles.

[308] Cuomo 2007, p84, who compares the task to recovering a history of Roman women, children, or slaves.

[309] Ulrich 2007, p12 notes that by the early 4th century, "Roman tradesmen were required to belong to their appropriate guild or *collegium*, which was one way of locating practitioners and imposing the dreaded *collatio lustralis* (tax every five years on merchants and craftsmen). By this time the normal Roman had lost his freedom to change professions, almost every son followed his father's footsteps."

[310] Ulrich 2007, p9 notes that the evidence of carpenters working together in large numbers includes the documentable evidence of *collegia* and their *scholae* meeting places. Ulrich also notes that the largest projects, including military tasks, commercial ship-building, and most importantly public construction, would have required high numbers of subcontracted and coordinated woodworkers.

[311] Listings compiled by Ulrich 2007, p13.

adzes, axes, drills, knives, lathes, planes, saws, clamps, hammers, mallets, wedges, glues, fasteners, and ropes.

At the Basilica of Maxentius, the majority of these tools were employed in concrete vaulting, bricklaying, and perhaps most importantly, carpentry. Taylor introduces carpenters (*fabri* or *fabri tignarii*) as “the unsung heroes of Roman architecture,” boasting that their skill and intelligence governed the formwork, technical construction, and structural stability of the entire project.[312] Although physical evidence of their handiwork is extremely rare, woodworkers placed their stamp on nearly every large-scale project constructed in the Roman Empire, especially the buildings employing concrete vaulting.[313] The forms for these vaults were termed “some of the greatest wooden roofing armatures ever erected in the Roman world” by Ulrich in his treatise on Roman woodworking.[314] These structures not only duplicated the precision and inflection of the eventual brick-and-concrete vaults above, but also supported the loads while assembly, pouring, and curing took place. The stability of the entire structure was based on the lack of deformation and distortion of the wooden support framework below.

The technique of centering relied on a consistent supply of thick sawn wooden boards, prepared in workshops and stored on site. These sometimes elaborate trusses and timber frames were large and unwieldy, constructed with strong joints capable of structural support, and probably assembled and hoisted into place.[315] The manufacturing principles of the timber support

[312] Taylor 2003, p178. Ulrich 2007, p8 designates the term *faber* (craftsman) for those of a skilled labor craft, and *faber tignarius* (beam craftsman) for a skilled carpenter working with wood.

[313] Ulrich 2007, pp59, 70-71; here the near-impossibilities of wood or wooden formwork of any kind enduring from antiquity brings the problem into focus. The joining techniques of lashing flax or hemp twine ropes and gluing wooden beams together are equally rare, with metal fasteners providing most of the physical remains of woodworking. Remarks by Pliny and others verify the use of glue and other fasteners, but most knowledge of wood formwork and scaffolding has been extrapolated from either Vitruvius or extant artistic representations.

[314] Ulrich 2007, p172.

[315] Ulrich 2007, p173; Ulrich extrapolates his model for timber centering from post-classical comparanda, and acknowledges that each construction site and project most likely used techniques that were specific to that project.

trusses present an interesting case of materials usage, as the strategy relied on both overbuilding and adaptive reuse. Many of the sawn boards could have been re-appropriated for other support configurations as construction proceeded upwards, but Roman contractors most likely overbuilt these very armatures to insure the structural stability. The simplicity of the board types needed for construction (long rectangular beams or flat boards) was most likely undermined by the continued reduplication of armature support members. Thus, it is difficult to estimate the exact amount of timber needed on site. Procurement and delivery were easier tasks than overall appraisal of materials needed and re-ordering.

The overall assessment of timber required for use at the Basilica of Maxentius is daunting, based on the number and sheer scale of engineering tasks attempted. In the context of the ten largest spaces ever built in the Roman world, the basilica is the sole example that spans a rectangular area without a truss.[316] The central cross-vaulting of the basilica, in combination with the simultaneous construction of the largest barrel vault ever built at the neighboring Temple of Venus and Rome, created possibly the largest and most ambitious centering network ever attempted.[317] These two projects tested the limits of spaces that Roman technicians would dare to

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Masters and apprentices learned and employed new strategies at each turn. By the Late Empire, concrete-vaulted structures had advanced by leaps and bounds, and the Basilica of Maxentius deployed an ingenious solution to span what is widely thought to be the largest vaulted space in antiquity. This solution, although not directly known, has been theorized by Amici 2005, pp136-144 among others, including Lancaster 2005 in more general terms for concrete-vaulted construction.

[316] Ulrich 2007, p149; with accompanying chart of ten largest spaces of the Roman world, formulated by Ulrich. The treatment of this central hall is the most notable departure from earlier basilica form, as it explicitly shifts from a conventional timber-trussed post-and-lintel system to the contemporary brick-faced concrete vaulting employed by architects since the Roman architectural revolution, discussed by MacDonald 1965, pp41-46, and pegged to the period inaugurated by the Fire of 64 CE and the accompanying rebuild by Nero. The era was marked by the introduction of brick-faced concrete construction as an aesthetic, rather than functional architectural technique.

[317] Ulrich 2007, p85; noting that the Temple of Venus and Rome preserves some examples of the formwork needed to span such a large space. The north retaining wall illustrates formwork with heavy posts 1 Roman foot thick and wide, spaces 4 feet apart, planks for the outer skin, and the insinuation of heavy diagonal props to hold the shuttering in place as concrete was added (as no transverse beams have been recorded). Also, see Lancaster 2005, p138 for the addressing of the 30-meter cross vaults and 24.5-meter barrel vaults at the Basilica of Maxentius.

span, which Ulrich records at about 100 Roman feet.[318] These daring spans were accompanied by appropriate structural problems, and both Ferretti and Lancaster and provide a succinct analysis of the vaults' failing.[319] The vaults spanning these distances employed an elaborate system of formwork that stressed the entire timber industry in Rome. For each task, planners arranged direct and consistent access to a ready stock of strong straight timbers, beginning with shuttering for the foundations, continuing with framing the lowest horizontal elements, and concluding with the "flying" configuration of the upper vaulting formwork.[320]

Although formwork, framing, and shuttering required the largest number of wooden planks at the ready, the most important supplementary function of allocating a consistent supply of timbers on site was for use in manufacturing construction implements.[321] Timbers were frequently employed for large wheeled contrivances that were put to use in a variety of diverse applications related to bulk transport, on-site maneuvering, and heavy lifting in quarries and work zones. Several examples of joined timber construction have been previously mentioned in this study, and consist of large cranes built on spoked-wheel principles and hinge up-righting

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[318] Ulrich 2007, p85.

[319] Ferretti in Giavarini 2005, pp161-178, 224-226 and Lancaster 1997, pp 36-37; the remaining barrel vaults exhibit significant deformation at their crowns, and even the patterning of the brick voussoirs has been disturbed by deformation of wooden centering devices and the substantial vertical stress instigated by the massive weight of the vaults. In addition, it appears that the lateral thrusts exerted on the vaults, in combination with the elevated height of the northwestern wall, increased the need for exterior support at the end of the basilica. As a result, buttressing arches were erected between the building and the immediately abutting Forum of Peace.

[320] Ulrich 2007, p175-176 notes that two types of formwork configurations were plausible: a semicircular truss armature that functioned as a logical development of prior roof-framing systems, and a spoked half-wheel armature which was assembled in a similar manner to the aforementioned treadmill cranes. This technique was known to have been used at Trajan's bridge over the Danube River, as a curvilinear form was described in order to span great distances, rely less on singular massive beams, and disassemble easier. All of these characteristics were desirable at the Basilica of Maxentius. It is also of note that concrete-vaulted structures never exceeded the limitations in place for spanning trussed halls in the Roman world, making the vaults essentially an exhibition in engineering prowess.

[321] Ulrich 2007, pp83-84; here Ulrich unequivocally states that as most buildings in Italy were footed by foundations of concrete, wood shuttering formworks proved to be extremely important to avoid wasting any concrete. As wood was not usually left in place after construction, the archaeological record of foundational shuttering provides us with an idea of the size and number of wooden planks necessary on site at any moment.

mechanisms.[322] The stresses and demands placed on the rotating components of construction cranes were quite different than those placed on equivocal transport wheels designed for road travel, which created a need for on-site engineers capable of operating and fixing the implements. On observation of the Haterii Relief crane reveals that the wheel spokes were attached by pins or pegs, which is useful for creating strong joints, interchanging components easily, and possibly reusing implements at different job sites.[323] This exact contingency was appropriate for Maxentius' larger combinatory worksite, as several of the implements and technicians were made available for use at both the basilica and the Temple of Venus and Rome.

The widespread on-site distribution of standardized timbers and re-use of large-scale wooden construction implements demonstrates the necessity of streamlined work flow patterns, and the continued symbiosis of the construction process within the urban network (see Figure 31). Every phase of construction saw large numbers of wooden planks,

Figure 31: Masons working on a building, with bricklaying and wooden scaffolding. Wall painting from Tomb of Trebius Iustus on the Via Latina, Rome (early-4th c. CE). British Museum, London, Inv. 299939.

[322] The crane mechanisms proposed in Chapter 3 are based on a variety of studies by Ulrich 2007, pp210-212, Adam 1999, p46, and Zimmer *Romische Berufsdarstellungen Archaologische Forshungen 12*, Berlin, 1982, p159. These constructions are consequently based on imagery like the Haterii and Capua reliefs, and specifically on passages in Vitruvius *De. Arch*. 10.1, where the author posits that machines (*machina*) were made from a 'unified assemblage of joint timbers' with a capacity to lift heavy weights. These contraptions were moved by large disks (*circulorum rotundationibus*), which were operated with a human-component 'motor' which rotated the central axel by shifting weight. Ulrich states that these immense wheeled crane motors could be up to eight meters in diameter.

[323] Ulrich 2007, pp210-212.

tools, and joining materials join the already organismic flow of construction materials to the building site. In a process mirroring the quarrying and transport of massive marble monoliths, each timber used in scaffolding or formwork was first harvested in the mountainous forests of Italy (or beyond), cut and shaped at lumber yards, shipped or floated down miles of waterways, collected at off-site storage bureaus, and readied for use on site. Storage depots distributed at the Emporium and outside the city may have collected massive wooden beams from like firs or larch trees and cut them in workshops, or received a steady supply of universal-size timbers from the far-flung lumber yards, depending on the ease and standardization of the Late Imperial lumber industry. In either case, the timbers were transported in large numbers from these depots to the building site, and housed in multi-faceted material staging areas and storage facilities built for the task. Workshops were also arranged to allow on-site carpenters to finish the timbers, replace damaged parts, and assemble the implements and formwork. As demand for wooden support members continually increased during the tasks of concrete-vaulted construction, the relationship between the material storerooms and the supply locations became more tacit. At this point, the reliable interplay between building tasks and material staging areas was the engine that drove the entirety of the construction process. The location of staging areas was inherently dependent on the size, organizational structure, and prerequisites mandated by each material or workshop, the existing topography of the city center, and the phasing of construction at the Basilica of Maxentius.

4.4. The worksite is shaped by its topographical fit, physical foundations, and context

The largely combinatory worksite of the basilica was framed by its inclusion as the centerpiece, both literally and figuratively, of Maxentius' massive building plan in the southern

Forum Romanum (see Figure 32 for the following diagrammatic arguments). The vaulted halls of the basilica were to take their place between the smaller 'Temple of Romulus' to the

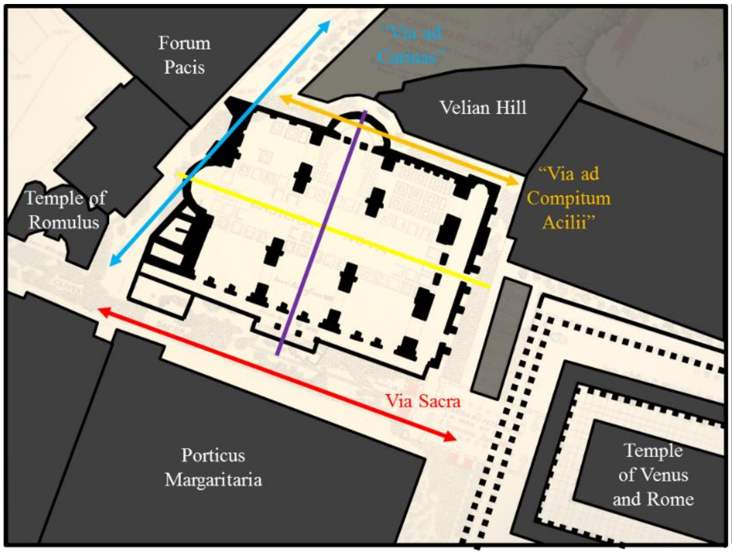

Figure 32: Diagram of Basilica of Maxentius and immediate surroundings. Yellow indicates primary East/West axis. Purple indicates secondary North/South axis. Note the three roads surrounding the Basilica of Maxentius, in blue, red, and orange.

northwest, and the larger Temple of Venus and Roma to the southeast.[324] This layout certainly contributed to the expedient construction of all three monuments in tandem, but most likely stressed the material supply networks, organizational structure of each site, and the physical makeup of each building footprint. In fact, the Basilica of Maxentius' site was so cramped that two through-roads had to be re-positioned, and several existing structures demolished.

The basilica displaced the *aedes penatium*, the *horrea piperatoria* spice warehouses, and a few private homes, and the demolition work carried out by Imperial architects on the Velian Hill cleared a comparatively large space for the foundations of a new building to fill the entire

[324] The small but poignant Temple of Romulus would serve as the connecting piece to the Forum proper, while also emphasizing Maxentius' dynastic aspirations and familial piety. Guidobaldi *The Roman Forum*, Rome: Mondadori Electa S.p.A., 1998, p61, Cullhed 1994, pp53-55, and Coarelli 2006, pp108-111 have advanced theories on the origins of this temple, ranging from a cenotaph for the Gens Valeria and a rebuilding of the ancient Temple of Jupiter Stator which was combined with the Penates shrine. Dyson *Rome: A Living Portrait of an Ancient City*, Baltimore: Johns Hopkins University Press, 2010, p351 notes that the formulation of this topography was palpably tied to the correlations and sightlines that it created, both by virtue of the bonded notion of these stereotypically Roman monuments to the new 'Valerian dynasty,' and by the imposing presence of the Temple of Venus and Roma that dominated the approach from the southern end of the Forum.

newly-vacated open area.[325] The Basilica of Maxentius was constructed in the space created between Vespasian's Forum Pacis and the large plateau created by the Temple of Venus and Roma.[326] The layout of the Basilica of Maxentius has proven very contentious over the history of its scholarship, but the recent seminal study by Giavarini and Amici has posited the most satisfactory explanation of its axial arrangement.[327] The Maxentian plan for the basilica specified a longitudinal axis paralleling and preserving the entirety of the Flavian-Neronian Via Sacra, which was over twenty meters wide, and paved an absolutely straight path from the southern forum to the foot of the Temple of Venus and Rome.[328] This axis was perpendicular to two small roads on the west and east sides of the site which originated in the center of the Forum and fed out in a northerly direction towards the Carinas and Subura residential districts. As a result of these boundaries on the west, south, and east, expansion of the site was only possible to the north, though inherently difficult because of the slope of the Velian Hill. The planners thus used

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325 Although the basilica needed to be prominent to maintain the visual acuity of Maxentius' new 'forum' plan, the site restrictions had a major impact on the design of the basilica, as it was no longer possible to adhere to proper Vitruvian basilica proportion (although as mentioned earlier, Vitruvius was writing during the Late Republic, and may have been out of fashion by the 300s in any case). Thus, a new hybrid basilica solution was proposed. Vitruvius' rules for laying out basilicas are completely discarded in favor of this new aesthetic, which is in fact based on the style of bathing complexes of the era. Vitruvius *De. Arch*. 5.3.4-5.3.5 specifies that the width of a basilica should be no more than ½ its length (whereas here the value is almost ¾ the length), and that the porticoes be ⅓ of the width of the central space (whereas here there are no exterior porticoes, but when substituting the interior side aisles, the ratio would be almost ¾).

326 Amici in Giavarini 2005, pp26-27; For location, Guidobaldi 1998, p61 mentions that the entire Maxentian 'complex' lies within Regio IV (Templum Pacis), while the Forum Romanum to the west of the Basilica Aemilia is considered Regio VIII (Forum), and the south including the House of the Vestal Virgins lies in Regio X (Palatinum).

327 Amici "Chapter 2: From Project to Monument" in Giavarini 2005, pp38-47. In note 16, Amici posits her explanation for how errors in reading the axes, entrances, and building phases of the Basilica of Maxentius have been made. She traces these errors principally to the study made by Nibby in 1819 (see Nibby *Del Tempio della Pace e della Basilica di Constantino*, Roma, 1819), where it was assumed that since the northern apse was a part of the second 'Constantinian' building phase, the corresponding southern entry was also part of the later building phase. Based on the 2005 study of construction and chronology of individual elements, and a typological study of basilicas, Amici states unequivocally that a basilica-type building built in Rome would require an entrance on the long side, especially in the case of such an important and significant street as the Via Sacra. It is thus implausible that the southern entry was planned only in the Constantinian building phase, and should belong in a discussion of the Maxentian building phase.

328 Amici in Giavarini 2005, p26; consult caption for Fig. 2.7.

the strategy of the previous Neronian builders, and simply further excavated the hill.[329] The transverse north/south axis of the basilica was perpendicular to the Via Sacra, and contained the primary entrance to the central hall.[330] The straight axis of the Via Sacra thus preserved an organizing principle for the basilica.[331]

While foundational work was carried out, contractors must have taken advantage of the prevailing proximity of the Basilica to other structures, and located staging areas and workshops near the well-trodden thoroughfares. At this point, the construction process of the Basilica started to nest itself in the city, and test its ability to symbiotically expand into the existing urban fabric. The beginning of work at the site would be by nature reductive, and in this case, the foundations of the basilica would cannibalize some of the existing architectural and physical topography. However, part of the initial reconstruction work took advantage of prior structures and substructures on the site, which recycled as opposed to wasted known material resources. The Flavian spice warehouses called the Horrea Piperataria were demolished, but their substructures were somewhat preserved and integrated into the Basilica's foundations.[332]

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[329] Ibid; the area had been heavily redesigned after the Fire of 64 CE, and Nero had incorporated much of the district into his Domus Aurea plans. Nero excavated part of the Velian Hill, and placed some structures of his house near the top of this excavated hill. Amici states that Nero had pushed at least to the area where the Forum Pacis now stands, and the Flavians then took over or replaced his building plans in this area. The Flavians reclaimed the western reach for the Forum Pacis, and built the aforementioned Horrea Piperataria spice warehouses (which would be razed by Maxentius).

[330] The southern pronaos had already served to create a transverse axis through the basilica, but an apse at the northern termination of this axis which was added by Constantine complicates scholarly opinion. Cullhed 1994, following Minoprio's 1930 study, believes that the southern entry was also added by Constantine, and was not integral in the original planning of the structure. This study thus assumes a southern pronaos in the plan.

[331] Amici in Giavarini 2005, p40. The relatively tight space for such a large structure, in combination with the uphill approach along the Via Sacra, created a strongly oblique view of the Basilica's façade, and created a perfect sight line through to the massive rebuilt Temple of Venus and Rome. Viewers traveling eastwards out of the Forum would pass the small Temple of Romulus, ascend the slope of the Velian Hill, find their eye drawn up along the trabeated façade of the Basilica, and look directly at the Maxentian rebuild of the Temple of Venus and Roma (notably, at the cella that held the cult statue of Roma).

[332] Amici in Giavarini 2005, p26; also in pp21-25 is a description of the phasing of the Horrea Piperataria, and the practical and propagandistic aspects to the Flavian reconstruction of the area over the Neronian foundations.

The Basilica was eventually placed on the same level as the northeastern terraces of the Horrea Piperataria, and further referenced the platform level of the adjacent Temple of Venus and Rome. The road linking the two prior structures thus had to be addressed by the Maxentian planners. The "Via ad Compitum Acilii" running along the north end of the Basilica site had initially been repositioned by the Neronian modifications to the area, which scaled back the Velian Hill and provided a retaining wall meant for larger structures (see Figure 33). Nero never built the above structures, but the buttressing and the subsequent Flavian modifications set up a pattern of molding the Velian Hill for an expansion of forum topography.[333] Maxentian construction would further profile the Velian, as the basilica footprint was over twice the size of the displaced Horrea Piperataria, and pushed north past the Neronian retaining walls.

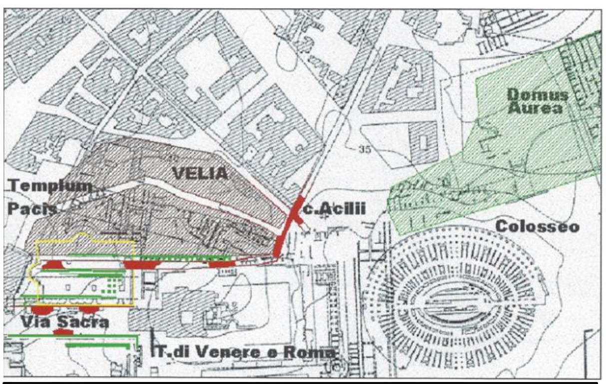

Figure 33: Relief map of Basilica of Maxentius environs, with modifications made by Nero. Red hatching indicates the Velian Hill, with "Via ad Compitum Acilii" running through the center. Yellow indicates the impending Basilica plan. Image reproduced from Amici in Giavarini 2005 (Fig. 2.3, p23).

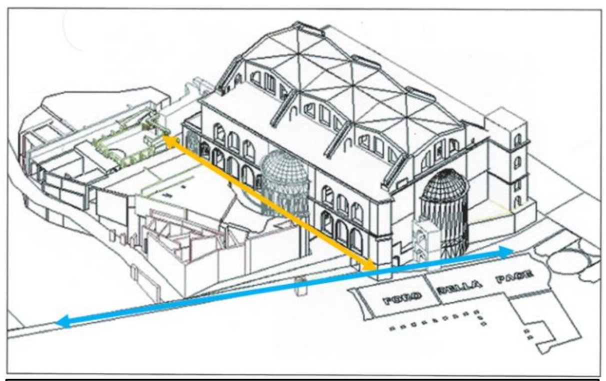

Figure 34: Axonometric projection of Basilica of Maxentius and the adjacent Velian Hill segments. Orange indicates the new position of the "Via ad Compitum Acilii." Blue indicates the new position of the "Via ad Carinas." Image reproduced from Amici in Giavarini 2005 (Fig. 2.13, p31).

[333] Amici in Giavarini 2005, p23; also consult Fig. 2.3 and the accompanying caption for an explanation of the archaeological diagram citing Neronian and Flavian modification to the area. Amici's Fig. 2.4 pictures these formidable Neronian substructures.

At this early juncture in the construction process, builders had already begun one of the highest volume tasks of the entire project, and scaled back the Velian Hill a further thirty meters.[334] In addition to excavating the girth of the Velian, laborers simultaneously demolished a large part of the Flavian-Trajanic era villa perched at the top, and razed a section of the Neronian substructures at the bottom. Eventually, the Maxentian project would take advantage of these Neronian-era foundations on the north, south, and west sides.[335] As the excavations continued, a large retaining wall was created to buttress the Velian and define the northern and last border of the construction site.[336] The road to the Compitum Acilii was now modeled to follow the north and east borders of the basilica, and repurposed as both a necessary street for urban circulation and a practical perimeter road for construction tasks (see Figure 34).

The last of the site's perimeter roads on the west side was perhaps the most difficult to redefine. The extant Via ad Carinas had previously passed at an angle between the Forum Pacis and the Horrea Piperataria, and led towards the Carinas neighborhood up the gradual slope of the Velian Hill. But as the Velian had been significantly cut back, and the basilica expanded the footprint of the warehouses to the north and west, the Via ad Carinas would now be completely severed by the connection between the basilica and the Forum Pacis. Here again is a direct manifestation of symbiosis. The insertion of a new monument and its growth during the process of construction immediately demanded a re-mapping of the city's pathways. The architect of the basilica repurposed the Via ad Carinas to run through a tunnel created by joining three sections

[334] Amici in Giavarini 2005, p27.

[335] Amici in Giavarini 2005, Fig. 2.8 caption; Amici states that it is probably not coincidence that only the portion of the basilica that was built north of the Neronian substructure wall did not collapse over time, as it was the only part of the building built on previously undisturbed terrain (this was the Maxentian-excavated section of the Velian Hill).

[336] The continued excavation of the Velian Hill yielded a great deal of earth, which was theorized by Amici in Giavarini 2005, p27 to have been used as fill on site. This would have been a solution to the problem of several different terraces levels of the basilica, as each successive load of earth would have been deposited at the lower levels on the west side to create the support for the foundations as the builders moved to the east.

of barrel vaults within the building's foundations.[337] The tunnel was built narrow enough to minimize the compression effect of the foundations, and varied its shape and direction according to the expected loads of the abutment walls above. The new placement and orientation of this street had to coincide with the creation of the northern perimeter road, as the two roadways initially differed in level by six meters. Thus, the Via ad Carinas rose while the new Maxentian perimeter road descended to meet it.

The formation and connection of these two perimeter roads, along with the simultaneous excavation of nearly 40,000 square meters of material and the demolition of warehouses, retaining walls, and other impediments, made a resounding impact at the southeastern entrance of the Forum.[338] This volume of activity, in tandem with the rebuilding of the Temple of Venus and Rome a few steps away, must have shut down the entire area for a period of weeks or months. It would have been highly unlikely that any pedestrian could have made their way from the south edge of the Forum proper to the western reach of the Colosseum Valley without a degree of difficulty, and this circumstance would exist even before the roads would have been crowded with thousands of oxcarts full of materials for delivery. In truth, this influx of materials began far before the populace of Rome noticed any vaults rising at the site, or anticipated the transport of large marble columns down the roads. It was the initial excavations, demolitions, and foundations that began percolating the networks of the construction process.

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[337] Amici in Giavarini 2005, p30, Fig 2.12 caption.

[338] In the absence of a concrete number of how many square meters were excavated, a simple geometric formula was employed. The excavations were estimated to push back at least 30 meters into the Velian hill, and were carried out over the breadth of the building plus at least a few meters on each side (100 meters). This produces 3000 m² at the ground level. The digital reconstructions found in Amicic in Giavarini 2005, p31-35 imply that the north retaining wall was approximately half the height of the barrel vaults of the side aisles, which would estimate at 10 meters. This would produce at least 30,000 m² of material. If we also estimate a wedge of material from the height of this bottom terrace to the height of the Flavian-Trajanic villa near the top, this should add at least one-quarter of the original material. Thus the final estimate could be near 40,000 m² of material excavated.

4.5. The worksite invades the Roman city: material staging and on-site workshops

The Basilica of Maxentius included a daunting quantity of materials, and myriad advanced engineering techniques. The standard construction tasks of bricklaying and concrete-mixing made the majority of on-site materials and tools compulsory, and dictated the pervasiveness of skilled workmen (*fabri*) and their guilds (*collegia*). At the immediate outset of groundwork, the Basilica's base structure would have required a large-scale coordination of materials, including wood, fasteners, baskets, and ropes for the formwork, and lime, pozzolana, aggregate, and water for the pouring of concrete foundations.[339] Concrete construction requires a large quantity of water, and a steady supply would have been required from early on in the planning stages.[340]

Maxentian projects in the city center probably relied on unfettered access to the Aqua Claudia, which ran along the Caelian Hill and terminated on the Palatine.[341] Access to a ready supply of water is tacit for Imperial projects, as a key tenet in concrete construction, a likely cleaning agent for tools and other odd jobs, and the nourishment of the hundreds of manual

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[339] See DeLaine 1997, pp91-94 for a discussion of timber, baskets, and ropes utilized in formwork and scaffolding. These materials, in addition to the ingredients and procedures for concrete and brickwork, will be investigated in the following chapter.

[340] Mindess and Young *Concrete* (2nd Edition), Upper Saddle River NJ: Prentice Hall, 2003, state that in a cubic meter of modern concrete, the mixture is made up of 600 pounds of cement and 300 pounds of mixing water. According to these guidelines, every cubic meter of concrete would be 1/3 water. DeLaine 1997, p131 describes the necessity of water supply from the earliest stages of construction at the Baths of Caracalla. Although the nature of the *thermae* project itself would necessitate water on a continual base through its functional use, DeLaine posits that work on a branch of the aqueduct "must therefore have been one of the priorities of the construction programme." There is no evidence for a diversion of an aqueduct for the construction of the Basilica of Maxentius, but the proximity of the project to a variety of Imperial aqueducts probably made the supply of large quantities of water a bit easier on site. Also consult Taylor 2003, pp79-84.

[341] For Roman aqueducts, see Frontinus *De Aquaeductu Urbis Romae* (c.70-104 CE), Hodge *Roman Aqueducts & Water Supply*, London: Duckworth, 2002, and van Deman *The Building of the Roman Aqueducts*, Eastford CT: Martino, 2004 (first pub. 1934). The Aqua Claudia is the main source of water to the Palatine area, thus the central city, other aqueducts like the Aqua Virgo (terminating in the Campus Martius), and the Aqua Appia or Marcia (terminating at the Aventine) could also have been used.

laborers on site.[342] Water storage contributed mightily to the shrinking amount of ground area available at the Basilica and surrounding staging areas. Transport and distribution of water was ubiquitous onsite, and water management probably employed its own staff. The constant running of container carts to the southern Forum added to the frenzy of activity, and stressed the transport avenues as well. An easier solution was to divert an arm of an aqueduct for use at the several Velian projects, but it is unlikely that Maxentius carried this out given his urgent timeline.[343]

Water may have been the easiest of the materials to secure in the center of Rome, owing to the extensive system of Imperial aqueducts, but the rest of the desired materials would necessitate an immediate use of the vast infrastructural networks of construction also present in the city. The water brought to the site would have been combined with the lime and pozzolana to create a cement to mix with an aggregate to form basic foundational concrete.[344] This concrete would be poured into spread footings that were slightly thicker than the structures that they would support.[345] A standard approach for pouring foundations in Roman building projects was to dig initial trenches to mark out the footings, and shore them up with wooden shuttering "walls" that would resist pressure from the outer trench walls and retain the concrete material

[342] Although here nourishment of the workmen with water is deemed important, a further issue considering the human quotient of construction work is the feeding of the labor. If thousands of workmen were on site during the normal workday, it seems that three options can be forwarded: either they brought their own food, they left the site for food, or they were provided food. The most efficient method of keeping workmen focused and on site is to have mass meals at midday, but the cost of furnishing a banquet for thousands of workers for hundreds of days per year would steadily mount, and disrupt the budget. Also, it is worth noting that the workers needed locations to relieve themselves. Rome is noted for public latrines, but unless a set of latrines was close, management must have thought to provide such a service (lest the situation encountered with oxen cleanup occur on site).

[343] Precedent does exist for the diversion of an aqueduct to serve one particular project, as DeLaine 1997, p131 attests to at the Baths of Caracalla. Here, Caracalla created a branch-line, called the Aqua Antoniniana.

[344] Adam 1999, pp65-79; Adam covers the manufacture of lime and mortar, and writes specifically on mixture in construction on pp76-79.

[345] Taylor 2003, p76.

held within.[346] The wooden framework was then left in place to rot away, and the concrete surfaces are forever left with a jagged profile to key into the surrounding earth, maximizing the friction.[347] As the foundations were laid, the masons would work within the trenches on either side of the wall, making sure to remove the transverse wooden struts and construct relieving storm drains.[348] When the set ground level was finally reached, the trenches on both sides were filled in, and the entire project shifted from foundations and substructures to walls and piers.

This juncture was absolutely critical to the entire construction process, as DeLaine frames the setting of the foundations as "the most critical stage for the transfer of an architect's design."[349] Once the foundations of the basilica had been laid, only small adjustments could be made to the entirety of the structural piers, exterior walls, and even nave and side aisle vaulting.[350] The complicated nature of vaulting such incredible spans at the Basilica of Maxentius made the initial defining of the site and laying of the foundations paramount to its success. The overall construction site needed to be controlled with machine-like efficiency, and in order for the initial demolition, excavation, and foundational works to proceed without incident, it was important to establish a center for administration.[351] The establishment of a central control center must have been one of the first suggestions of an impending building

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[346] DeLaine 1997, pp135-136; MacDonald 1982, pp154-156; Lugli 1957, pp385-387; Taylor 2003, p77; Adam 1999, p108.

[347] Taylor 2003, p77.

[348] Taylor 2003, pp78-79.

[349] DeLaine 1997, p133.

[350] Ibid; DeLaine describes several discrepancies in the laying out of the *natatio* at the Baths of Caracalla; some of these are described as "dimensional inaccuracies" within an acceptable 1% error range, but others are said to indicate a schism in the relaying of design to construction. Careful investigation of these errors led to the conclusion that they may be due to a single initial mistake in laying the building foundations on the ground.

[351] DeLaine 1997, p131; DeLaine admits that no evidence exists of administration centers, or even equipment and material depots. As argued in her study, as well as this one, it would be impossible to build a large-scale project in ancient Rome without some sort of centralized direction for each step in the entire construction process. The following points are in illustration of that fact, and presume the existence and relevance of such a governing force at the site. As mentioned above, the modern equivalent of an organizational model is provided by BIM.

project in the city; its presence was necessitated for the initial checking in of materials and labor, as well as the characteristic source of direction and feedback for the site. The physical space of the administrative center would also contain the drawing board for architects and engineers, as well as possibly storage for architectural drawings, scale models, and other basic design implements.[352]

The most important function of the administrative center was to distribute and organize the worksite, and this included setting up depots for equipment, mapping out storage areas for materials and implements, establishing smithing facilities for advanced tools, designating areas for handling and working materials, and defining and securing the site parameters.[353] The worksite of the Basilica of Maxentius was constrained by buildings on the east and west, and bounded by the excavations of the Velian Hill on the north, which meant that any and all of the administrative centers and staging areas must have been to the south of the construction area. This meant that the comparatively small area between the upper Via Sacra and the Palatine Hill was most likely filled with these

Figure 35: Mosaic of a building site. From Musedu Bardo, Tunis, Inv. A264. Photo by author.

[352] Taylor 2003, pp27-36 and Figs. 4, 7-12; architectural drawings and relatively crude area maps showing buildings with and without wall thicknesses are known from Rome and other sites, most notably the funerary plaque from Rome, now in Perugia (Taylor Fig. 4). This particular example shows three buildings, including the floor plan of the Temple of Castor and Pollux near the Tiber River, with differing scales and wall thicknesses. Scale models were also made to convey a sense of space, and communicate to a largely semi-educated base of artisans that needed to understand the mechanics of the building apart from architectural drawings. The preferred material for models was wood, which does not survive, but there are a few examples of stone that inform the understanding of such models.

[353] DeLaine 1997, p132.

functions from the inception of the design process. In addition to the administrative elements keeping very tight quarters, there was also a strict attention paid to the support arteries which existed in absolute tandem with the more static entities on site. Pits for the slaking of lime and smithing workshops had to share limited physical space with transport avenues and staging areas for scaffolding timbers and bricks.[354] Scheduling was an explicit concern, and while some local materials arrived daily, other large-scale materials depended on a complete choreography through the city to take their place in the building hierarchy (see Figure 35). It is therefore important to understand the character of the Roman city as a host for the basilica's construction process, and to trace the intensification of the contact between site and immediate urban context.

A responsive consideration of the overall building site necessarily includes the basilica's foundations and Velian excavations, and the accompanying spillage of staging areas and other organizational fodder into the Colosseum Valley, the Forum proper, the usable valleys between the Palatine, Capitoline, Oppian, and Caelian hills, and possibly into the porticoed spaces of the Imperial Fora and the open part of the Circus Maximus.[355] Some of the areas in the closest proximity to the basilica are also comparatively the smallest, and transport avenues would partially block any substantial conglomeration of material and equipment storage. Architects and site foremen were forced to be creative with solutions to a material staging issue that would by nature mount as the process continued. The massive influx of materials for Maxentian building projects certainly placed stress on the still-sprawling metropolis of Rome, a fact magnified by both the Tetrarchic-era political uncertainty and the crucial focus on the city's infrastructural networks. Building tasks had a direct impact on the streets and monuments of the city. Favro

[354] The tenor of this argument is introduced in DeLaine 1997, p132.

[355] The following conclusions about site location, storage and materials placement, and staging areas are again based on analysis of the 1979 Scagnetti map of Imperial Rome.

notes that during crucial times of construction in the center, statues were relocated and areas of the paved Forum floor were protected by sand and straw to avoid damage.[356] This readying of the city as a host organism for the symbiont construction process is an illuminating metaphor for how mutualistic relationships take physical shape.

Although Rome's population had most likely "dwindled" from its Trajanic height of over 1,000,000 to a still-dense 800,000, the early 4th-century city was certainly physically and topographically larger in most respects than even a century prior (see Figure 36).[357] The seaports of Ostia and Portus, the Emporium river wharves along the Aventine, and the Appian and Flaminian gates still teamed

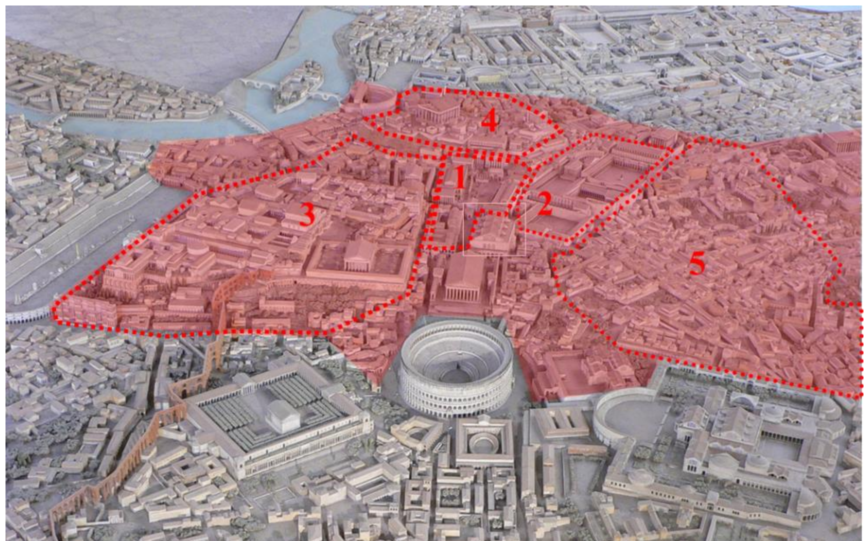

Figure 36: Detail of *Plastico di Roma Imperiale* model (I. Gismondi: Museo della Civiltà Romana, 1933-1955). Red overlay highlights the density of the (1) Forum Romanum, (2) Imperial Fora, (3) Palatine, (4) Capitoline, and (5) Subura at the outset of the Constantinian age (310 CE). The Basilica of Maxentius is indicated in white.

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356 Favro in Laurence and Newsome 2011, p350. Favro suggests that important monuments like the Umbilicis Romae and the Rostra may have been moved or relocated to avoid damage, but this is considering construction of the adjacent Arch of Septimius Severus.

357 Krautheimer 1980, pp3-4 estimates during the era of the Adoptive Emperors put the population of Rome between 1,000,000-1,500,000 people. The population most likely decreased during the Third-Century Crisis period, although emperors continued to build and move the city outward, capped by the Aurelian Walls in the 270s. This structure moved the boundaries of Rome further than ever before, and seemed to allow for more topographical growth. Krautheimer notes that the network of highways leading outwards from Rome had been maintained, and the systems of trade, ports, and physical infrastructure had flourished during the middling period. Even a conservative estimate 800,000 people in 300 CE would rank Rome as the world's largest city, according to a variety of anthropological sources: Morris *Why the West Rules – For Now*, New York: Farrar, Straus and Giroux, 2010; Modelski *World Cities: -3000 to 2000*, Washington DC: FAROS, 2003; Chandler *Four Thousand Years of Urban Growth: An Historical Census*, Lewiston: The Edwin Mellen Press, 1987; Rosenberg "The Institute for Research on World-Systems; Largest Cities Through History" (The Etext Archives); Chandler and Fox *3000 Years of Urban Growth*, New York: Academic Press, 1974.

with commercial activity, and the Maxentian material supply chains would be forced into a timeshare with other industry. Most of Rome's administrative components were still held intact, and each unit held court in its own appropriate district in the center. City government resided in several preserved offices from the High Empire, including urban, provisioning, and police prefects, aqueduct, riverbed, and sewer supervisors, and harbor, building, and streets officials.[358] Although Rome's political influence had waned since Diocletian's decentralization and provincialization, the senatorial class still existed to furnish the city with a wealthy aristocracy, an adjusted *cursus honorum*, and administrative and ceremonial duties. City councils, magistracies, and legal administrators still had a home in Rome, as evidenced by the impressive extant collection of legal documents from late antiquity, as well as the expressed necessity of Maxentius to create a judicial basilica in the forum.[359] Rome's quality as a living, working city had not diminished throughout the various late antique attempts to destabilize its foundations, and its constant interchange would not easily be disrupted by the breadth of Maxentius' ambitious building program.[360]

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[358] Krautheimer 1980, pp4-5.

[359] Harries *Imperial Rome AD 284 to 363: The New Empire*, Edinburgh: Edinburgh University Press, 2012, pp13-19; Harries states that maintenance of city councils were a consistent imperial priority, and disputes any break in juristic tradition or 'vulgarisation' of law in late antique Rome; praise instead goes to the collection of extracts from imperial legal enactments during the Constantinian age, and the records for creations of 'laws' as response to provincial legates and later bishops. Also see Harries *Law and Empire in Late Antiquity*, Cambridge: Cambridge University Press, 1999; Matthews *Laying Down the Law: A Study of the Theodosian Code*, New Haven: Yale University Press, 2000; Humfress *Orthodoxy and the Courts in Late Antiquity*, Oxford: Oxford University Press, 2007, and the essays collected in Rich ed. *The City in Late Antiquity*, London: Routledge, 1992.

[360] It stands to reason that Maxentius actually sought to stir up activity in the city center, because of his position as defender of the Roman people (particularly inside the city of Rome). Maxentius likely tried to commemorate his ambitious building program immediately, possibly with celebrations and spectacles. No records exist of such activity, owing to Constantine's equally ambitious program to wipe out the deeds and persona of Maxentius. However, his restoration of the Temple of Venus and Rome had many undertones of civic and religious pride. Marlowe "*Liberator urbis suae*: Constantine and the ghost of Maxentius," in Ewald and Norena eds. *The Emperor and Rome: Space, Representation, and Ritual*, Cambridge: Cambridge University Press, 2010: 199-220, pp201-202 states that as recently as 248 CE the Temple had been the centerpiece of Philip the Arab's vast celebrations for Rome's 1000th birthday. Quite possibly the several Temples and other buildings that Maxentius was completing functioned as showpieces for a larger idea of Roman spectacle (as argued in the previous chapter), although the construction noise, dust, and density may have obscured such plans.

The core districts of Rome (*Regiones* IV, VIII, X, XI) teemed with activity, as the Forum Romanum and the Imperial Fora held the majority of political, religious, judicial, and commercial functions for the city.[361] In terms of topography, the northernmost Forum of Trajan began an unbroken line of defined spaces that terminated only at the new Maxentian structures. Across the spur of the Arx, the temples of the Capitoline Hill also began a sequence of buildings that bottlenecked the Forum Romanum along its southwestern edge, running all the way through the Atrium Vestae and several Palatine residences. These thickly grouped palaces gave way on the south to the Circus Maximus, which furnished one of the largest open areas in all of central Rome. The Forum Boarium linked the circus to the Pons Aemilius, and held a large collection of warehouses and markets. Although extremely busy, this forum area was kept open by law, and may have functioned as a relieving point for construction traffic and an alternate possibility for material staging and delivery.[362] The other major relieving area was located off the eastern head of the Circus Maximus, in the valley between the Palatine and Caelian Hills. The 'Via Triumphalis' bridged this valley with aqueducts, but the roadway remained one of the widest and straightest thoroughfares in Rome. As discussed earlier, the 'Via Triumphalis' may have functioned as a primary delivery mechanism for the more substantial building materials to the Basilica of Maxentius, as it led from the Colosseum Valley to the old Porta Capena.[363] This juncture then funneled traffic to the eastern exit of the city along the Via Appia, or southern

[361] Central districts, for this purpose, are defined as Regio VIII: Forum Romanum, Regio X: Palatium, Regio IV: Templum Pacis, and Regio XI: Circus Maximus. These districts were the most geographically central in Rome, as well as being physically smaller and easiest to define.

[362] The Forum Boarium was so busy and at risk for encroaching buildings that Platner and Ashby 1926, p223 state that boundary stones were erected to protect it and keep it open for all commercial activity.

[363] The Porta Capena area, although not well understood in its later antique form, might also have been key for material staging and administration of Maxentian projects, because of its position at a key junction, its capability to hold a large amount of supplies, and its relative proximity to the basilica.

access to the Emporium material supply wharves along streets skirting the base of the Aventine Hill.

Apart from these key core districts, the rest of the makeup of central Rome was mostly unconducive to aspects of construction traffic and material staging specific to the Basilica of Maxentius. The area to the immediate north of the basilica was characterized by the extremely dense Subura residential neighborhood, and the Quirinal, Viminal, Cispian, and Oppian hills that defined it. The compact and hectic nature of the Subura, and the elevation changes inherent to the several hills in close proximity would have made maneuvering and storage difficult, if not impossible. The Aventine Hill was also rendered difficult by virtue of its high urban density and elevation, and was bounded by the Circus Maximus, the Emporium yards, and the Tiber River. The vast Campus Martius lie to the northwest of the city center, but this area was also topographically dense and was mostly obstructed from the forum by the Capitoline and the Tiber River. In terms of proximity to the construction site, the Maxentian planners were probably left with areas of the Esquiliae, Caelimontium, and Isis et Serapis districts to attempt to store and arrange building materials (see Figure 37). However, with several predefined areas nearer to the

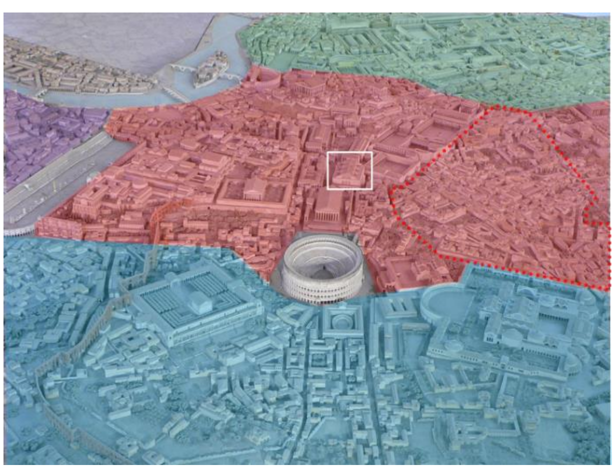

Figure 37: Detail of *Plastico di Roma Imperiale* model (I. Gismondi: Museo della Civiltà Romana, 1933-1955). Red indicates the dense city center (with Subura highlighted). The Basilica of Maxentius is indicated in white. The other dense districts are the Campus Martius in green and the Aventine in purple. The least dense areas closest to the center are indicated in blue, and include Esquiliae, Caelimontium, and Isis et Serapis.

building site, it is unlikely that these areas would strictly be relied upon, outside of the possibilities for storage along supply routes to the south.

Supply networking and material organization would certainly drive many of the decisions that led to the steady encroachment into the city, but it was the construction process' reconnoitering of different avenues that defined the process of forming a symbiotic relationship. The basilica and the city now had to simultaneously occupy the same infrastructural arteries, and sometimes the same physical space. The city's intake mechanisms, which previously supplied the organism with its diverse needs, now performed the tasks of the construction process as well. Ports, warehouses, and wharves now performed dual functions, and road capacities were overtaxed. Material manufacturers and quarries located to the south of the city now forced their products continuously through the several gates of the Aurelian Walls, while sea shipments arrived daily to saturate the ports. Rome and the Basilica of Maxentius gradually forged a mutualistic relationship for an indefinite period of time, and the construction process functioned as the mechanism for this amalgamation. The first stage of understanding this complex relationship is a fundamental investigation of the shared infrastructural frameworks of construction, the second stage is a discussion of the uses and expression of process within the larger urban context, and the current final stage is an evaluation of the practical functionality of large-scale building on site.

4.6. Coordinating the worksite: organizing workmen, planning the workday, timing tasks

Successful administration of the worksite was contingent on a variety of factors, including readiness of workers and materials, efficient organization and allocation of daily tasks, and a hierarchy of management that clearly understood the total undertaking, and was able to effectively communicate seasonal construction goals and clearly articulate the anticipated final product. The plethora of skilled *fabri* in Rome guaranteed the quality of workmanship, and the relatively consistent pattern of building throughout the city assured a largely capable staff of foremen. An experienced architect with a seasoned staff of contractors and a strategic delegation tree lessened the likelihood of missed deadlines. Synchronization is an important issue in running an effective construction site. Each material or supply needs to arrive on site at a preordained time, and each specialized crew of workmen must be placed appropriately to take advantage of their talents. Rapid contractions of the infrastructural networks of the construction process assured that each effective agent was furnished with the tools and materials to coordinate a task. In Imperial Rome, best-laid design plans often lead to flawless construction technique, but the site administrators also possessed the ability to manage adversity. The likelihood of damaged or lost materials was still a factor, and even while utilizing a favorable building season, weather, religious proceedings, or socio-political events potentially undermined the construction schedule. In the case of the Basilica of Maxentius, the much publicized death of the patron during the latter stages of construction likely produced at least one work stoppage. The precision inherent to large-scale Roman building indicates that an impressive administrative hierarchy and system of task allocation was responsible for timely construction in the face of myriad unforeseeable variables.

Like many Roman projects, the Basilica of Maxentius benefitted from a clear-cut sequencing of building operations and a conceptual separation between functional core and decorative veneer.[364] The entirety of the structural configuration and its chief engineering tasks were carried out well before the assigning of wall revetments, marble flooring, and other

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[364] Fitchen 1986, p53.

ornamental flourishes. As mentioned earlier, even the massive Proconnesian marble columns were non-load bearing, and most likely erected late in the process of construction. For the first few years of construction, masonry work, foundations, and carpentry comprised the majority of site tasks rendered monotonous only by their repetition, consistency, accuracy, and precision. These tasks were overwhelmingly simplified because of material supply and staging technique. The process of pouring concrete for foundations and retaining walls is immediate evidence that staging areas and workshops were assembled during the first days of construction. Work areas for mixing aggregate, pits for slaking lime, and separate collection areas for materials are all elemental in laying footings, and were among the first delineated zones characterizing the site. Even at the earliest stage of building, several hundred cartloads of materials were brought into the city center, while demolition tasks simultaneously sent several hundred cartloads away from the site. Carpenters were hard at work, assembling shuttering formwork and scaffolding to match the rising of masonry walls. In light of this multi-faceted manufactory, it is conceivable that nearly every major construction material was present on site from the first months after groundbreaking.

Although the Romans are widely noted for their developments in concrete-vaulted construction, foundations in particular were notoriously finicky because of the necessary avoidance of uniform heat and drying while the liquid cement sets.[365] This problem is exacerbated by the Mediterranean climate, but tempered by the incremental compartmentalization and leveling courses employed by the workmen. The deliberate consistency in the handling of structurally-important foundational elements defines the success of the overall edifice. Cracks and other imperfections must be identified early on in the process,

[365] Fitchen 1986, pp81-83.

so adjustments and re-pours can be made.[366] Once the foundations are satisfactorily in place, planed, and cured, building proper can occur. At this stage, the building crews multiplied, and the construction site experienced a drastic influx of materials. This circumstance demonstrates exactly what we expect from the infrastructural networks of a living and adapting city. Brick and mortar staging areas were added incrementally outside the boundary of the worksite, but close enough that masonry workmen had access to materials, tools, and plans. As walls grew in height and girth, carpenter's workshops were increasingly active creating scaffolding to rise along with the crew's working platform. Eventually the walls rose to dozens of feet high, and each scaffolding level was built upon the next to support the tasks inherent to a 12-hour or longer workday. At this early stage of construction, it was important to establish perimeter roads behind the rising walls and access pathways through the site to afford proper access to workmen, and thoroughfares for material delivery. The dramatic sloping of the site meant that the eastern access points on grade with street level were maintained as long as possible.[367] Eventually it became important to either rough-build sloping ramps to deliver materials, or use crane implements to raise them up to where they were needed.

Construction proceeded from west to east, beginning with the massive structural pier over the Via ad Carinas at the northernmost corner, and the large apse crowning the westernmost point of the basilica floor.[368] Amici suggests that similar technical characteristics in the walls of the north apse, buttressing arches, and northern wall indicate that they were built by specific

[366] See Lancaster 2005 for relevant sections on the requirements of pouring Roman concrete. Also consult Adam 1999, pp177-191 for concrete vaults, and the references for Choisy *L'Art de batir chez les Romains*, Paris, 1873, and the relevant plates, which Adam deems irreplaceable for technical observations despite the age of the study.

[367] Amici in Giavarini 2005, p155.

[368] Ibid; Amici specifically enumerates through Plates 1-36 in *5.5 Building Procedures* the assumed course for construction, based on structural studies and analysis of the details of wall facings of the extant basilica sections. In Amici's chapter 5, the overall construction is estimated, but based on the construction of the extant third of the archaeological remains, which have been exhaustively studied.

masonry crews in the same construction phase.[369] The northern masonry sections and accompanying scaffolding rose concurrently, and the crews on each side of the wall responded to the new barrier they were creating between them by building in "construction windows" so that they could communicate with each other through the duration of each phase.[370] The crews were deployed to several areas at once, but were distributed precisely to make each workday goal attainable and avoid costly work stoppages. As the perimeter wall progressed southward, workmen were then tasked with constructing the buttressing walls of the side aisles. The structural precision of the buttressing walls and subsequent barrel vaulting was paramount to the success of the project, as the later cross vaulting over the nave was built directly on these foundations.

During the erection of the perimeter walls and eight structural piers, the construction site must have appeared as an organized chaos, with a distributed labor energy quotient. Several different construction crews worked on separate sides of walls, at unequal heights above the floor, and in distinct zones distributed about the site. The sheer amount of bricks needed at disparate points necessitated a precise systemization to allow each crew to maintain a predictable pace, and keep every crew member out of each other's way. There was a constant and heavy material stream in and out of the site, with a multi-directional system of "construction roads" that could accommodate two-way travel. At this early juncture in construction, the site may have been defined with a roughly gridded organization, to avoid a large intersection in the middle that would clog the distribution arteries.[371] Perhaps similar principles of off-site material networking

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[369] Amici in Giavarini 2005, p129.

[370] Amici in Giavarini 2005, pp129-131; evidence for one of these construction windows is photographically captured in Figure 5.7, and another "construction door" is recorded in figure 5.9.

[371] Here it must be mentioned that a construction site may have taken on the properties of the cohesive planning template of the Roman *castrum*. No matter how tentative a military outpost had been, Romans chose to arrange and layout a large grid with set entrances, distribution corridors, and a central collocation area. Most Roman planned

were applied here as well, to demonstrate that a mutually beneficial symbiotic relationship between supply lines and site topography were not relegated to construction infrastructure.

Most materials were staged near to or within the building site, but the remaining distance covered delivering the cargo combined with the heft of each payload required a degree of planning. Regardless of proximity to site, each shipment was loaded, secured, delivered, and unloaded where needed. A comprehensive planning mechanism was employed to determine which specific zone on site needed bricks at a certain time. An ordered distribution system was also useful for spot-checking all materials, quality control, and assuring that each segment of construction was uniform.[372] Material porters may have had set distribution patterns scheduled by foremen on each morning of construction, and they were certainly inter-coordinated to avoid delays in materials arrival, duplication of stock, and order mistakes. The material staging zones were similarly organized; each stock collection area was extremely adaptable, and continuously accommodated both freight arriving from off-site brick kilns and cargoes departing for the building site. Each storage area was continually inventoried, and staffed by its own crew of workmen. The foreman of each crew also coordinated with other material staging areas, to organize the many disparate supplies for brick-faced concrete-vaulted construction.

As the perimeter walls and buttressing arches were completed, the burgeoning construction project was readied for vaulting. This process continued to employ a majority of the materials needed for foundations and walls, including bricks, mortar, concrete constituents, and

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cities relied on these principles as well. It is not improbable that a construction site would rely on similar principles, with the possibilities of straight, gridded, and orthogonal "roads" precisely laid out for each zone.

[372] Amici in Giavarini 2005, pp129-130 specifically mentions that several areas (sometimes in different locations) of basilica construction are so uniform that they were must have been done by the same building crew. The fact that some wall sections were constructed without a *bipedales* course means that each crew probably had their own style of masonry work, utilizing roughly the same materials, but with differing daily needs. A larger organizational system would address these subtle discrepancies. This implied hierarchical system would also avoid singular carts of material wandered around the site by workers shouting "who needs bricks?"

wooden support members. However, in addition to the amplified danger inherent to working at dizzying heights, the complicated centering techniques deployed in vaulting generated an entirely new phase of construction. Each vaulting task was complicated by a compulsory diversification of materials and required additional carpenters and engineers on site. Vaults relied on each structural variant of the constituent support system below, and required an appropriate level of attention from the project architects. Systematic access to continually rising reference points during building made it necessary to erect each side aisle barrel vault concurrently, a process that taxed the entire system of the construction process.[373] In this more advanced phase, the entirety of large-scale concrete construction was on display, and nearly every type of labor crew was employed. Master masons and other bricklayers modified the walls, engineers and architects planned the vaulting, carpenters built and adjusted scaffolding and centering devices, material supply porters navigated the contracting floor spaces below, and foremen assembled a plan to upright the massive marble columns of the central hall (see Figure 38).

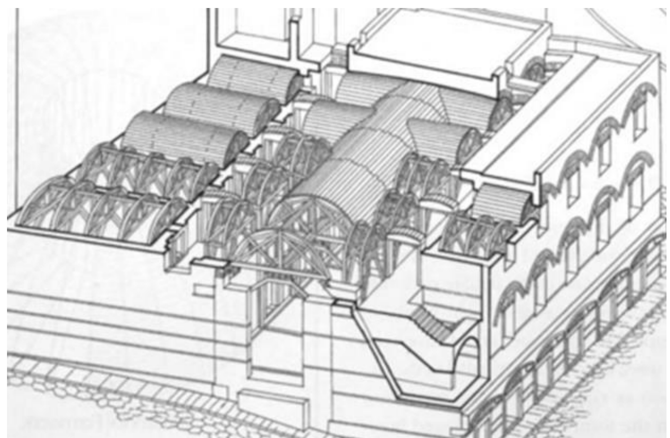

Figure 38: Reconstruction drawing of the centering formwork at the Aula of Trajan's Markets. Image reproduced from Lancaster 2005 (Fig. 30, p39).

During the process of concurrently erecting the side aisle barrel vaults, the once-fluid construction access spaces began to close up. Both of the basilica's side aisles were filled with centering formwork and other construction implements, and the perimeter roads on all sides were

[373] Amici in Giavarini 2005, p142 also mentions that the physical requirements of just one side aisle were 86 meters in length, 17 meters in width, and began at 26 meters above floor level.

nearing completion. The organizational principles employed at the onset of building were significantly modified. Even without the use of the “construction ramp” on the now closed-off western end of the basilica, materials and workmen still needed to access the central areas of the site. In fact, the sheer amount of bricks, mortar, and concrete components had increased for the massive central cross vaults, and now they had to be lifted at least 26 meters above ground to arrive at their destination. The amount of energy required for construction rose exponentially with the height of the walls. Even if the carpenters had built “flying” centering implements for the vaults, and these devices were cantilevered above the basilica floor, scaffolding was still necessary for workmen and materials to arrive at their high destinations.[374] Cranes and pulley mechanisms were also employed to fetch materials from far below the construction level (see Figure 39).

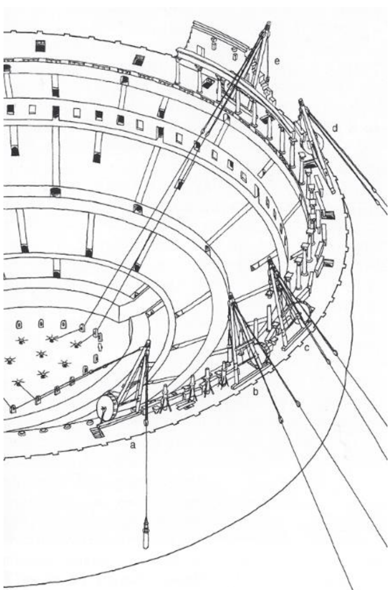

Figure 39: Reconstruction drawing of cranes and pulley systems employed for construction and other lifting tasks at the Colosseum. Image reproduced from Taylor 2003 (Fig. 96, p171).

The organizational system of material distribution outlined above was deployed at this phase of construction as well, and the results were likely underscored because of the more enhanced dimension of height to the vaults. As each compartmental level of the concrete cross vaults set, a fresh set of materials was required to continue the process. The builders desired a consistent and predictable settling for the concrete vaulting, and the confluence of every requisite material and craftsman was necessary in order for the vaults to be structurally sound. The cross vaults had a multi-directional system of lateral

374 Ulrich 1986, pp172-176.

thrusts on the piers below, and they were articulated by a continuous series of brick ribbing.[375] The brick ribs were carefully arranged by hand and applied at the same time as the pozzolana-based concrete into the wooden formwork. This technique, perfected by the Romans, insured minimal structural deformation and allowed for a great degree of control over the settling and curing of the concrete sections.[376] Timing remained the most tacit of all building concerns, and the success of the vaulting relied on a larger network that distributed materials to the correct place on site at the opportune time. Each material staging area was innately connected with all the others, and the basilica's architect must have been acutely aware of the entire inventory of supplies and the methods for furnishing them as needed on site. As each workday concluded, the materials and workmen would reset, with a weathered eye towards each new task.

4.7. Finishing materials and tasks, estimated timetable for completion of all building

As a result of the significant amount of time spent on each building activity, each workday likely ended without a neat conclusion of a specific task. Walls and vaults were not completed in just one day, which meant that foremen had to consider the precise state in which they left each task, and workmen had to resolve their tools and materials. Upon closing for the day, the work site was treated with the same consideration and organization that had defined the Roman construction process. No work zone, staging area, workshop, or routing corridor was left in disarray, as the first cartloads of materials the next day required clear paths to traverse a complicated site. Some material loads were likely assembled and stationed at each work area ahead of sunset, to promptly encourage the completion of each task in the new day. As construction proceeded upwards, more care was taken in securing tools and implements.

[375] Amici in Giavarini 2005, p134.

[376] Amici in Giavarini 2005, p135.

Building materials were expensive, and the site was likely cordoned off from the public overnight. As lavish marble revetments and other adornments began arriving in the late phases of construction, more appreciation was given to safeguarding the site.

As the completion of all vaulting neared, material requirements slowly changed. Bricks, mortar, pozzolana, water, and other materials were increasingly absent on site, save for use in modifications and amendments. The exorbitant supply of these materials likely waned in their on-site depositories and staging areas, but some storage zones remained full until project completion. The staging areas that had been established further from the construction district were no longer needed, and the site shrank to include only necessary workshops. However, the symbiotic relationship that the construction process had formed with the larger urban context was still intact, and remained so throughout the progression of finishing. As mentioned earlier, Roman projects are noted for their distinction between structural shell and decorative program, but the two processes are separated only by time, and not by organization, infrastructure, complexity, or location. Adornments like plasters and stuccoes still utilized intact procurement and distribution systems.[377] In fact, the stucco workshops required to carry out the massive decorative program inside the basilica may have been equal in scale to some of the other workshops. Stucco is composed of most of the same ingredients as masonry mortar, and constituent elements of powdered aggregate and lime/gypsum binders created a workable thixotropic paste that was steadfastly cared for by on-site artisans.[378]

[377] Giavarini 2005, pp111, 117-118 for plasters and stuccoes at the Basilica of Maxentius. The entirety of Giavarini Chapter 4 is devoted to the description of specific materials at use on site, including structural and decorative materials. The stucco decoration program in particular is rather intricate and far-reaching, as Giavarini (and Monaco) estimate that the total linear extension of the stucco decoration, including the stuccoed coffering of the side aisle barrel vaults, collapsed nave, and apse, is about 12 kilometers. This estimate includes only those based on extant archaeology, and does not consider other decorative programs that we cannot know about.

[378] Giavarini 2005, p116. Giavarini mentions that stucco putty actually required a longer quenching period than normal lime putty, which may insinuate an involved production process near the construction site.

Decorative marble revetments and columns required heavy machinery to hoist them into place on site, and construction implements and scaffolding were quite obviously required for these tasks. The Via Sacra façade of the basilica employed several columns of red porphyry which were nearly half the height of the perimeter wall (about 7-8 meters high), which would have employed lifting machines similar to those described to hoist the interior Proconnesian monoliths into place. The chromatic decoration of the basilica was clearly exhibited on both the exterior façades and the interior surfaces, and no expense was spared in the final adornment phase. Giavarini concludes that the entire floor of the basilica and all of the interior walls were covered with marble revetments, which results in a total surface area of 12,000 square meters (conservatively estimated at 1600 tons of marble).[379] Even at the end of construction the basilica was crowded with scaffolding on the interior in order to raise each marble revetment and paint on the stucco decoration, and sparsely dotted with cranes and pulleys on the exterior for each lifting task.

The distribution of workmen throughout the site remained constant through the construction and finishing period, but the bricklayers and masons were steadily replaced by artisans and marble handlers. Engineers, carpenters, and lifting specialists remained active from start to finish, and architects stoically guarded the overall building program throughout. Task by task was completed, and the work site shuffled its needs as each workday concluded. Structural building was replaced by decoration, but all necessary materials continued their influx into the city center from off-site workshops and quarries, until work was complete. The total building time for the Basilica of Maxentius is difficult to estimate, in large part because certain tasks of finishing and decoration are thought to have continued under Constantine. The construction of

[379] Giavarini 2005, p119, assuming each slab was an average of 5cm thick, and marble weighs on average 2700 kg/m³. The amount of material needed is then paired with the appropriate amount of labor in an energetics analysis, investigated below.

the basilica probably commenced soon after Maxentius usurped power in late 306 CE, and most likely concluded soon after his death in 312 CE. Most of the structural complement was achieved in six years, and the impressive speed likely owed to the impending political uncertainty. Even while Constantine continued/finished the decorative program, the infrastructural arteries advancing outward from the basilica sustained their form and activity until the last supply arrived for use. Only then would the networking tenets slowly collapse into the urban topography again, and the intensely mutual symbiotic relationship forged between the construction process and the city would exhaust its usefulness.

The eventual atrophy of this relationship is not immediately apparent, as each component of the construction process has a slightly different useful period and physical imprint. There was no sustained train of material carts exiting the city simultaneously as building tasks concluded. Left over materials and reusable implements like oxcarts and tools were simply returned to their initiation points, and stored until the next building project triggers the infrastructures of construction into resuming. Some materials like wooden scaffolding or standard brick types were likely re-appropriately immediately during construction, and delivered to another of Maxentius' projects. Entropy at the end of the project thus concludes the base calculations used in architectural energetics, although restoration work during the latter eras of Rome held the propensity to begin the entire process again. Spoliation of building materials was also the norm during the late Empire, and marbles were re-appropriated so many times that the original provenance can be obscured.[380] The Emporium and other storage yards were famously kept so full of collected marbles that the reserves from Roman antiquity were never used up.[381] In this

[380] This circumstance is inherent to the Basilica of Maxentius as well, as the large Proconnesian monoliths were speculated to have been spoliated from Hadrian's Temple of Serapis by Taylor. This preponderance has been enumerated in Chapter 3, and considered for its possibilities here.

[381] A theme echoed earlier in this study by Fant, Herz and Waelkens, Pensabene, and others.

manner, the construction process for each monument continues to leave traces of its existence behind, whether it be found in archaeological remains or presupposed from known material sources and literary references to engineering technique. The penultimate task of finishing each construction process does not end the forged symbiosis within its contextual environment. The monument itself has an enduring life beyond its manufacture and functional use, and this life stretches backwards and forwards through time, and outward across several thousand kilometers of networks and paths. In order to fully understand any monument, we need to interrogate the dynamic systems which irrevocably render it as part of a whole.[382]

[382] Many thanks to Diane Favro, Chris Johanson, and Dana Cuff for providing insightful commentary on this dissertation, and helping me fully formulate my principal theory for the study of the Roman construction process.

5. Conclusions: Evaluation of a Symbiotic Construction Process

5.1. Ancient evidence of a symbiotic relationship in the Roman construction process

The Basilica of Maxentius was built quickly in a tightly confined spot near the topographical center of Imperial Rome, during a time of incredible socio-political upheaval. Even placed securely in its context as a large-scale public building project, the Basilica and its foundations required a nearly incomparable amount of materials and featured a triumph of engineering never seen before in the Roman world. This specific building project required a remarkably ordered planning sequence, a demonstrated fluidity in material and labor supply, and a dynamic understanding and deployment of the infrastructural networks of construction. The extremely high quotient of efficiency produced during each task realization or material attainment references an inherently elastic framework. I have argued that this successful venture is made possible only with an implicit symbiotic relationship cultivated between the series of construction processes and the surrounding urban environment of Rome.

A multi-faceted system conducive to the construction process was continuously cultivated by the Romans throughout the Imperial period, from the development of the marble trade network during the Julio-Claudian era to the collection of *collegia* tradesmen guilds distributed throughout the city. Evidence collected from literary references and archaeological artifacts can help translate the widespread infrastructure of monumental manufacture into a legible conception of the mutual relationship forged between the construction process and the city. Recent scholarship has indicated a tacit understanding of the archaeological traces of such networking mechanisms, as it applies directly to the dispersal of goods and artisans in the Roman world.[383] I have illuminated several of the crucial systems at work within the city of Rome, and evaluated the push and pull of the symbiotic relationship with the construction process. The most intriguing aspects of this polemic reaction are the variable exertion of certain conditions by the city, and the resultant adaptability of the construction process. Conversely, the process has crucial needs to be met, and the urban context can sometimes be malleable to reverse exigencies of scale, quantity, and quality. As investigated in this dissertation, the city of Rome responded to the construction process with disparate mechanisms like urban topography, traffic dispersal, legal enactments, neighborhood context and density, labor availability, and socio-political desire for the spectacular.

The foundations and continual modification of such networks allowed for a uniform distribution of building materials and craftsmen for Imperial projects, which in turn streamlined the overall methodologies of the construction process. Indeed, a vast infrastructure custom-tailored to construction needs is the principal mechanism employed by Maxentius to achieve such an incredible rate of architectural building during his brief reign. That the Basilica of Maxentius was built in tandem with a wholesale modification of the largest temple in Rome and a vertical extension to the 15-kilometer circuit of the Aurelian Walls is a testament to the success of the networking construct. Although the industries of brick and marble were employed simultaneously for multi-faceted construction, it is important to note that each individual project required an independent organizational structure and complement of materials. Every successive condition had to be met in sequence for any tandem building or material sharing between

[383] See Poblome, Bes, and Willet "Thoughts on the Archaeological Residue of Networks: A View From the East," in Keay ed. *Rome, Portus, and the Mediterranean*, Rome: British School at Rome, 2013. This article posits a theory based on the trade of goods, and the archaeological evidence derived from case studies carried out by the ICRATES (Inventory of Crafts and Trade in the Roman East) in Boeotia, Cilicia, and Pisidia. Also cf. Keay "The Port System of Imperial Rome" and Wilson, Schorle, and Rice "Roman Ports and Mediterranean Connectivity" in the same volume.

Maxentian projects, as each task of concrete-vaulted construction was inherently reliant on the completion of the task immediately preceding it. But given the similarities in requirements, the erection of the masonry walls, concrete vaults, and marble columns of both the Basilica of Maxentius and the Temple of Venus and Rome were carried out roughly simultaneously. The ability to concurrently perform the large-scale engineering tasks of concrete vaulting depended on the number of qualified work crews available in early 4th century Rome. But based on the successful building program of Diocletian a decade earlier, the quantity of workmen and the precision in execution was characteristically reliable. Labor distribution plans, tool complements, implement availability, and material procurement models all indicate an overarching infrastructural system conducive to large-scale building in the Late Empire.

The theoretical insinuation and archaeological verification of such an organized network necessitates an increasingly dynamic conception of the methodologies for Roman Imperial construction. It is impractical, and even irresponsible, to present construction as a series of isolated projects in the context of an urban environment. Architectural building should be conceptualized in a more complicated milieu that considers details and mechanisms once considered superfluous. As a single block of marble travels from its quarries, through a series of holding ports and warehouses, to a material staging area and finally arrives on site, it will define a constantly-evolving artery of an organic supply network. The avoidance of material bottlenecking and injury to oxen drovers on the precarious streets of Rome problematizes the idea of swift and efficient building. Instead, a study of the construction process should embrace these variables and consider the complicating mechanisms. A more accurate picture of ancient construction includes a sliding index of efficiency, and the scrutiny of a malleable support infrastructure. The successful completion of an architectural monument is a direct function of the symbiotic relationship forged between the individual process of construction and the entire networking superstructure of the urban environment. The entirety of this infrastructural milieu acts as an incubator and hosts the various mechanisms of construction, and continually supplies the process with physical support and a structural organization.

The Basilica of Maxentius provides a succinct demonstration of such a mutual relationship, in that its extant physical structure is a wealth of archaeological evidence, its position in the central area of Imperial Rome severely complicates the manner of building, and the intricacies of its construction furnish several theoretical verifications of the spectacular manifestation of such a symbiosis. In tracing the archaeological and literary evidence for materials, labor, and effort employed at the basilica, it is increasingly necessary to implement the relevant techniques of site-catchment analysis, spectacle theory, architectural energetics, and other economic and technical methods.[384] Site-catchment analysis functions as a way of reverse-engineering construction, and was explicitly deployed in Chapter 2 of this study to collectively organize the entirety of building materials, and ascertain the time and effort required in bringing them to bear on monument construction. Chapter 3 relied principally on the conception of the spectacular, and its physical and literal manifestations in the city during construction. Architectural energetics buoyed the understanding of energy expended on the tasks of construction in Chapter 4.[385] Each methodology informs the ability and requirements of building in an ancient environment, and provides a lens in which to visualize the specific tasks of construction when only traces of physical evidence of the process exist.

[384] See Chapter 2 of this dissertation, and for relevant studies on site-catchment analysis, see Vita-Finzi and Higgs 1970, Roper 1979, Ericson and Goldstein 1980; for spectacle theory see Dodge 2011 and Dey 2015; for architectural energetics see Trigger 1990, 1993, 2003, Erasmus 1965, Abrams 1987, 1994, Abrams and Bolland 1999, and DeLaine 1997.

[385] These concepts also tangentially relate to the aforementioned methodologies of the *chaîne opératoire*, bottleneck theory, and the Theory of Constraints (as introduced earlier in Chapters 1 and 2).

Construction was such a consistently visible part of Roman culture, and by all accounts a source of great pride, that it is somewhat difficult to reconcile the lack of accounts and treatises that glorify the process. Physical evidence, such as post holes in walls and formwork markings in concrete foundations, can illuminate specific methods. Artistic representation found throughout the ancient Mediterranean can address certain lacunae in the overall processes of construction. The account of Vitruvius and illustrative markers like the Haterii Relief make visible the implements and devices required for building, and several additional contemporary accounts recall the clattering of wagons through the streets of Rome and the whirling about of gigantic columns and timbers. Similar feats of scale have been recreated in the post-Roman period by the likes of Fontana, Montferrand, and even Mussolini, and artistic renderings of these spectacular events increase understanding of the methods and energy expended in pre-mechanized building. Illustrative accounts of materials, workforce, and execution, in combination with the extant archaeological record at the Basilica of Maxentius, bring into focus the multi-faceted relationship that construction forged with myriad constituent parts and processes. Any successful explication of architectural creation must consider the existence of elemental infrastructural systems of construction, the topographical make-up of the contextual environment, and the socio-cultural milieu in which building occurs. This cross-disciplinary study addresses the construct of a governing symbiosis between the process and the environment.

In identifying this symbiotic relationship, the notion of the ancient building site as static, isolated, and linear has been necessarily repositioned. The construction process is instead a multi-directional, integrated, dynamic system with strong roots in an extant network of infrastructures. The primary proficiencies of the large-scale Roman construction networks are the sources, arteries, and faceted nodes utilized before and during the effective period of construction. The intramural cultivation of specific industries such as brick-making and quarrying, and the development of the massive marble trade network provided a foundational paradigm allowing for easy manipulation by Roman architects and planners. Perhaps the most substantial contribution of each individual building project was the management of adversity. Even the utilization of standardized transport avenues and shipping routes could not address all manner of accident, surplus, or pitfall. Each encountered problem was solved within the limitations set by the project, which consisted of maneuvering certain shipments of materials, re-appropriating work crews, or substituting reliable alternatives. It is virtually impossible to ascertain whether mistakes were made in supply or distribution, but on-site corrections can sometimes prove apparent in the archaeological record.[386] The final configuration of ancient building projects can change greatly based on supply inconsistency, most notably Wilson Jones' hypothesis of replacement columns inserted in the porch of the Pantheon.

Adjustments to the materials or appearance of a building can function as one type of slippage, in which the fluid relationship between supply infrastructure and contextual environment become visible at a precise moment. Another such instance in ancient Roman construction is provided by the spectacular. When a task of building or transport transcends its functional value, and is deemed watchable by the populace of Rome, the mutual relationship between the process and its environment becomes immediately visible. Several instances of this "spectacling" occurred during the construction of the Basilica of Maxentius, and were rightly celebrated. Wall paintings commemorate both mundane construction tasks and overall project

[386] Amici in Giavarini 2005, pp144-149 mentions several on-site mistakes and difficult fixes at the Basilica of Maxentius, including the difficulties created by working on a slanting site. Specifically, the lateral walls and relieving arches were modified at specific points during the construction, which is still visible in the excavations. Amici also mentions that although the remains of the basilica do not permit a global evaluation, the extant remains indicate that there were strikingly few errors committed in the building, including a 1% precision rate in dimensional differences in the bearing structures.

management, funerary markers render the craftsman's tools as worthy of artistic representation, and monumental architecture was promptly celebrated upon completion.

The Roman construction process is certainly not as celebrated in extant artistic and literary works as it might have been contemporaneous to building completion, but the imaging of this multi-faceted system has been increasingly pursued by modern scholarship. Studies on ancient construction have made incredible strides in re-creating technical achievements, categorizing specific materials and implements, and theorizing linear building procedures. Notable work by DeLaine, Lancaster, Taylor, and Favro have also considered individual construction projects, and attention has been dutifully paid to the intricacies and necessities of each particular process.[387] A focused interrogation of the pervasive infrastructural networks that allow for construction, and the resultant link of this overarching paradigm to a conspicuous large-scale project, remains a germane gap in scholarship.

In this study I have identified and enumerated the vast Roman networking grids that permit freight procurement, intra-city transport, implement distribution, labor organization, and material staging. In setting the Basilica of Maxentius as a case study, I have engendered an investigation of how the placement of a large-scale concrete-vaulted structure in the topographically-dense late Imperial city center can provoke all facets of the Roman infrastructural networks of construction, and induce a complementary reaction. The subsequent analysis examines the dynamic nature of the resulting symbiosis, and the critical points where this mutually beneficial relationship is seen within the fabric of the city. The Roman construction process is thus presented as a multi-directional and dynamic set of geo-temporal systemic links that persistently interacts with a foundational infrastructure housed within the topography of the nascent city. Each individual monument is in part determined by and partly determines the form

[387] DeLaine 1997, Lancaster 2005, Taylor 2003, Favro in Laurence and Newsome 2011.

and shape of its entire interconnected ecosystem, and by necessity cultivates a symbiosis with the networks of a constantly evolving built environment.

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