Human Labor and Harbor Capacity at Rome

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ABSTRACT

LANCE LAGROUE: Human Labor and Harbor Capacity at Rome

(Under the direction of Richard Talbert)

Rome was a unique city in antiquity with a population of one million people from late first century BC through the first two centuries AD. Such a vast size was not seen again until London in 1800. It was able to grow and supply itself with such a large population due to the vast resources of its Mediterranean Empire. However, many key constraints made supplying Rome difficult including its location upstream of a fast flowing river, limited sailing season, and vast quantities of imports needed. One of the key aspects to overcoming such constraints includes the integral role of dock workers and harbor capacity. This paper aims to reconstruct and suggest many of the aspects of Roman dock workers including their numbers, hiring practices, and unloading practices. The role of harbor capacity will also be reviewed to understand Rome's ability to safely import several hundred thousand tons and prevent famine.

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I. Introduction

Rome found itself in a unique position in antiquity with an estimated population of one million people from the late first century BC through the second century AD[1] No city in European or Mediterranean history reached such a size again until London around 1800.[2] The ancient cities nearest in populations were Alexandria, Antioch and Constantinople, but even at their peak, none contained half or more than half of Rome's population.[3] Generally, those cities which came closest in population to Rome possessed greater natural advantages. For instance, Alexandria claimed immensely productive land with a navigable river that flowed directly into the city. Similarly, Constantinople, founded as a port city, was located at the crux of the Aegean and Black Sea, thereby it was able to have quick access to goods from multiple regions. Unlike those cities, Rome had to exert all its talent, resources, and will power to maintain the largest metropolis in antiquity.

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[1] For discussion on Rome having one million people see T.G.Parkin, *Demography and Society at Rome,* Baltimore*, 1992, 91-133.* Also for a general discussion of population in antiquity see S.Hornblower and A. Spawforth,*The Oxford Classical Dictionary: Third Revised Edition,* Oxford, 2003, 1223.

[2] Most historians estimate that London reached one million people around the year 1800. In 1790 the population would have been close to this figure, but this is the preferred number for this paper as there is better data concerning shipping from London in 1790 than 1800.

[3] Alexandria held the second largest population in antiquity with over 500,000. The populations of Antioch and Constantinople ranged from 100,000-300,000.

Geography proved the greatest natural obstacle to Rome's ability to sustain itself. Due to its location fifteen miles inland along a fast flowing river, multiple problems arose. First, like most cities in antiquity, it depended upon sea borne goods to sustain the population. Second, road transportation simply became too expensive for large quantities, as it often cost up to twenty-eight times as much as sea and river travel.[4] But for Rome, sea imports took greater efforts since the fast flowing Tiber River and a heavily silted river mouth prevented larger and therefore more economically efficient vessels from going directly upstream to the city. Instead, vessels had one of two options. They could first stop at Puteoli just north of Naples and transfer their goods to smaller boats, which then went 120 miles along the coast directly then up the Tiber to Rome. The second option was for the initial sailing vessel to be small enough in size with a minimal draft so that it could overcome the silted river entrance and then stop at the town of Ostia at the mouth of the Tiber where they could unload or continue directly to Rome to disembark.

Rome maintained the haphazard method of utilizing Puteoli or smaller vessels through the Late Republic until the reign of Claudius. The consequences were considerable. The first effect was the expense of double loading and unloading since goods had to be unloaded and reloaded at Puteoli or Ostia before they even reached Rome. Utilizing such human labor in ports incurred heavy expenses. For instance, as late as 1961, prior to modern shipping methods that utilized the container box, the U.S. government estimated that shipping time (i.e. the time the vessel was on the water) accounted for only ten to

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[4] For discussion on transportation costs see R.Duncan-Jones, *The Economy of the Roman Empire: quantitative studies,* Cambridge, 1982, 366-399.

twelve percent of overall shipping costs while harbor operations accounted for sixty to seventy five percent of overall shipping costs.[5] Even a four thousand mile voyage could consume more than fifty percent of its shipping costs at port during the loading and unloading of its vessel.[6] Thus, the cost of loading and unloading a vessel was at least double that of the actual transport of goods. For ancient Rome, the double loading and unloading meant an inflated shipping cost of at least fifty percent more for nearly every item that arrived by sea.

The second difficulty that Rome faced during the Late Republic through Early Empire was lack of harbor capacity. Specifically, capacity in this context meant the amount of safe harbor space where a ship could unload. Although ships in antiquity generally did not require a deep water berthing, they still needed a harbor that could provide for the draft of a wooden vessel over 200 hundred tons. Furthermore, it was extremely likely that Rome during this early period prior to 64 AD could not provide a safe anchorage for the larger vessels. The consequence was further inflated costs to the shipment of goods and made Rome was more prone to traffic jams from the increased numbers of river skiffs and smaller sea vessels. Lastly, such a negative situation of increased traffic could ultimately lead to food shortages.

The lack of capacity had a second effect on Rome's ability to sustain itself. One of the key advantages of possessing a large harbor was the natural tendency for nearby

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[5] M.Levinson, *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger,* Princeton, 2006, 8-9.

[6] Ibid 21

warehousing to act as a secondary storage and distribution center. Without a large port at the mouth of the Tiber, it forced an overwhelming amount of concentration of warehousing to occur inside Rome. Such concentration was potentially dire, as Rome was situated in a river valley that experienced frequent flooding. Aldrete estimates that from the first century BC through the second century AD Rome experienced a large flood once every twenty years, and a year of extremely heavy rains caused an elevated Tiber river once every four years.[7] These periods of flooding and heavy rains occurred predominantly in the winter through early spring when food reserves were naturally low. If the grain stores became wet during a flood they would mold and thus be inedible. And since two-thirds of the Roman diet consisted of imported grain, this would result in widespread famine.[8] Adequate capacity and diversified warehousing were needed if Rome was to alleviate fear of natural disasters and famine.

This thesis intends to study several key aspects of Rome's ability to sustain its population. The first is a brief summary of the evolution of Rome's harbor system. The second is to seek an understanding of the integral role of human labor involved in the shipping process. Since adequate data from antiquity, in literary or epigraphic form, does not exist, a comparative study from the pre-modern will be used to gain insight, in particular to ascertain the relative number of laborers needed, time to unload vessels, and group organization.

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[7] G.Aldrete, *Floods of the Tiber in Ancient Rome*, Baltimore, 2007, 71-81.

[8] P.Garnsey, *Food and Society in Classical Antiquity*, Cambridge, 1999, 19-25.

The last aspect to consider is capacity. Of particular importance to this study is the way in which harbor capacity, or the lack thereof, cultivated vulnerability to famine. Moreover, special attention should be paid to the dock workers and ships, and their contribution to capacity. In summary, through a greater understanding of Rome's use of human laborers and harbor capacity, comes the knowledge of Rome's ability to sustain an extraordinary level of population and the resultant costs of such an endeavor

II. The Harbors of Rome

Recognition of the need for greater harbor capacity began under Julius Caesar.[9] However, his unexpected death in 44 BC thwarted his building ambitions. The civil wars and subsequent demands that engulfed the period following Caesar's death most likely curtailed any immediate thought for such a massive project, despite recognition of its necessity. Seneca continues to note that inadequate measures continued under Caligula, stating that Rome held food reserves for eight days during a period of shortage.[10] Lastly, four large floods from 54 BC through 5 AD all resulted in widespread famine due to the destruction of stored grain and severe disruption of shipping

The desire to building a new Roman harbor began anew under Claudius, roughly ninety years after Caesar. Suetonius recalls the prompting of Claudius' initiative when he states "A mob stopped Claudius in the Forum and pelted him so hard with curses and stale bread that he had difficulty in entering the Palace by a side-door; as a result he took all

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[9] Plut. *Caesar* 58.5

5 μηχανώμενος· πρὸς δὲ τούτοις τὰ μὲν ἕλη τὰ περὶ Πωμεντῖνον καὶ Σητίαν ἐκτρέψας πεδίον ἀποδεῖξαι πολλαῖς ἐνεργὸν ἀνθρώπων μυριάσι, τῇ δὲ ἔγγιστα τῆς Ῥώμης θαλάσσῃ κλεῖθρα διὰ χωμάτων ἐπαγαγών, καὶ τὰ τυφλὰ καὶ δύσορμα τῆς Ὠστιανῆς ἠιόνος ἀνακαθηράμενος, λιμένας ἐμποιήσασθαι καὶ ναύλοχα πρὸς τοσαύτην ἀξιόπιστα ναυτιλίαν. καὶ ταῦτα μὲν ἐν παρασκευαῖς ἦν.

[10] Seneca *De. Brev. Vit.* 18.5 *quod sciebat populo Romano superstiti septem aut octo certe dieru, cibaria superesse.*

possible measures to import grain."[11] Recognizing the continuing problems with importing food, Claudius finally decided to build a harbor to increase the capacity for importation of goods while minimizing the challenges.[12] Therefore, in response to the demands of the Roman populace, Claudius began construction in 42 AD, calling the new harbor *Portus,* which literally means "door or gate" in Latin.

Claudius had the option to decide between three types of man-made, or artificial, harbors. The first was a traditional Phoenician-Punic design, notable for its use of a *Cothon,* or a man-made cut-in inner harbor.[13] Cities such as Carthage, Utica, Moya, and Sidon utilized this type of design. The Hellenistic model represented the second type of harbor, which created long walls that jutted out and made a breakwater to provide shelter for ships.[14] The final harbor style was the Roman model. Roman harbors often mimicked the Hellenistic design, with the exception of the use of hydraulic concrete, rather than stones, for the creation of sea-walls. King Herod's harbor at Sebastos provides a key example of the Roman style.[15] For reasons not known, Claudius chose a modified version utilizing aspects of all three; he cut directly into the land in the Phoenician manner, but utilized long sea-walls that bore a closer resemblance to the Hellenistic model. Arguably, Claudius' architects

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[11] Suet. *Claudius 18.2 Artiore autem annona ob assiduas sterilitates detentus quondam medio foro a turba conviciisque et simul fragminibus panis ita infestatus, ut aegere nec nisi postico evadere in palatium valuerit, nihil non excogitavit.*

[12] Suet. *Claudius* 20.1 *Opera magna potius et necessaria quam multa perfecit…item emissarium Fucini lacus portumque Ostiensem..*

[13] A. Raban and E.Linder, *Marine Archaeology*, London 1975, 54.

[14] Ibid 57

[15] Ibid 58

thought this modified style would provide the greatest amount of protection against storms while being economically efficient.

Additionally, it is unclear why Claudius built the harbor north of the Tiber River, since there is a greater rate of silt accumulation north of the Tiber than to the south.[16] One of the common arguments for building to the north is that individuals living in the town of Ostia occupied the land south of the Tiber River.[17] Therefore, Claudius would have had either to evict them or to purchase the land below the river.[18] Claudius presumably did not wish to be encumbered by such a delay, and so built the harbor north of the river.

Perhaps the most remarkable aspect of Claudius' decision is the scale of the effort. The exact sum in financial terms for the harbor is unknown, but it is known that it took Claudius twenty-two years of labor, ending in 64 AD to complete the endeavor. The basin for *Portus* measured 1,000 meters across, the left mole over eight hundred meters, with an entrance of 120 meters.[19] Suetonius comments that this effort was greater than draining the Fucine Lake, an act which took 30,000 men working full time for eleven years.[20] Lastly,

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[16] R.Meiggs. *Roman Ostia*, Oxford, 1973, 54-58.

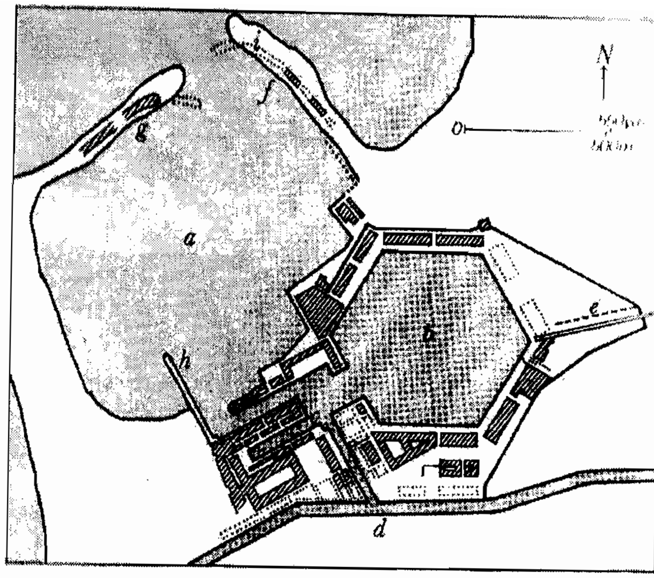
[17] Ibid 153

[18] Also, such relocating would have taken considerable time. Indeed, after the *London Dock Act* was passed in October of 1800, it took six years to finish harbor expansion in London due to the considerable time required to purchase and relocate 1,000 houses. G.Jackson *The History and Archaeology of Ports,* Kingswood, 1983, 58-59.

[19] Meiggs, 158.

[20] Suet. *Claudius* 20.2. *..fucini lacus portumque Ostiensem, quanquam sciret ex iis alterum ab Augusto precntibus assidue Marsis negatum, alterum a Divo Iulio saepius destinatum ac propter difficultatem omissum.* Even though the "official" opening was not until 64 C.E., parts of the harbor were clearly in use before then as Tacitus recalls the destruction of two hundred ships in harbor in 62 C.E. Tacitus *Ann.* 15.18.

two large canals or channels were created under the direction of Claudius, namely the *fossa Portuenesis* and the *Fossa Trainia.* The former was built to help alleviate the effects of flooding, while the latter provided ships a channel to bypass the silted entrance of the Tiber and proceed onward to Rome.



Fifty years after the completion of *Portus*, Trajan recognized the need to increase capacity and security for the now primary harbor and began a large expansion.[21] His expansion, deemed Trajan's harbor for this paper, involved a further digging out of the land directly to the east of *Portus.* The cutting created a *cothon* in the Phoenician-Punic manner, but with the distinction of utilizing a hexagonal pattern. Each side of Trajan's hexagonal harbor measured 357.77 meters.[22] Recent research at *Portus* and Trajan's Harbor indicate that *Portus* could safely dock 300 vessels, while Trajan's expansion allowed for a further 400.[23] Although Trajan's basin was smaller, each side was usable for unloading unlike *Portus* where part of the mole was not used as quay, thereby allowing Trajan's port greater ship capacity. Also, we may safely assume that the older facilities at Ostia allowed for at

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[21] Portus image from G.Bass, *A History of Seafaring,* London, 1972, 92. A= Portus Basin, B= Trajan's Basin, C=*fossa portuenesis,* D= *fossa trainia.*

[22] S.Keay, M.Millet, L.Paroli, and K.Strutt, *Portus,* Oxford, 2005, 38-39.

[23] Ibid

least fifty vessels. Therefore, a total ship allowance for the three harbors after 112 AD came to an estimated 750 vessels.

After the completion of *Portus* and Trajan's expansion, warehousing or *horrea* existed in three primary locations. All in close proximity to harbors to ensure efficient movement of goods from ships to storage. The greatest percentage was found near *Portus* and Trajan's harbor. Similarly, Rome had a substantial series of *horrea* located in the Emporium District near the Aventine hill and Tiber River. To demonstrate the immense size of the buildings, The *Horrea Galbana,* the largest warehouse in Rome covered 20,000^2 meters.[24] Ostia also contained multiple *horrea*, but not to the same extent as Rome or *Portus*.

For all three centers of *horrea*, the exact amount of space that is contained is difficult to calculate, as it requires knowledge of the height each individual *horreum,* when only the foundations remain.[25] Additionally, the construction of modern Rome buried much of the relevant sites, while the warehouses that were located next to Trajan's harbor are currently on private family estates and have been unavailable for research. Despite such difficulties, recent excavations indicate that the warehouse facilities at Portus and Trajan's harbor held a ratio of 3:1 to storage capacity at Ostia.[26] Furthermore, since it is known that

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[24] G.Aldrete and D.Mattingly, *"The Feeding of Imperial Rome" in Ancient Rome: The Archaeology of the Eternal City*, Oxford, 2000, 146.

[25] G.Rickman, *Roman Granaries and Store Buildings,* Cambridge, 1971, 121-123.

[26] S.Keay, M.Millet, L.Paroli, K.Strutt. *Portus,* Oxford, 2005, 302-303. The estimated combined total for *horrea* space in Ostia is 46,118 meters squared by the end of the second century. Portus&Trajan's harbor is estimated to have 145,072 meters square of warehouse space.

the *Horrea Galbana* in Rome held as much grain as nearly half of Ostia it seems reasonable to estimate the same ratio of 3:1 with Ostia.[27] Therefore the overall ratio of *horrea* distribution is suggested as 3:3:1 for *Portus/Rome/Ostia*.

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[27] Ibid. Admittedly, this is a rough estimation.

III. Human Labor at Rome's Harbor

Due to lack of ancient evidence, there is a great challenge in understanding many aspects about the porters working at Rome's harbors. The limited surviving material focuses on funerary evidence, providing some details about an individual's life. For instance, the Latin word for stevedore, *gerulus,* has only a couple of entries at Rome. For example, one entry records basic information that an individuals fathers who started as a porter at Rome, reached the status of *Decurion,* a position of status and wealth.[28] Other entries for *Gerulus* include the specific mentioning of *collegia,* or order of *geruli,* specifically, while another porter mentions that he had a "most agreeable" wife. The inscriptions, although fascinating reveal little about the numbers, hiring methods, and unloading practices, and as a result are only partially useful.[29] They provide some indication they were opportunities for vertical mobility for porters and could achieve wealth. However, those individuals who achieved notable wealth were probably very few in number. Furthermore, it is likely that these same individuals who could afford stone funerary engravings were also members of *collegia* which implies a certain level of leadership amongst the workers.

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[28] the Meviae Modestae / filiae pientissimae quae / vixit ann(i)s XIX / mensibus X dieb(us) / XXIIX hor(is) VIII Mevius / dec(urialis) gerulus Tychi/cus pater fecit / in titulo. CIL 06, 09439

[29] [Iu]ssu imp(eratoris) Caesari[s] / Augusti / gerulis ped(es) III |(dodrantem) // v(ivus) Cn(aeius) Pompeius Pompeiae Cn(aei) / Magni f(iliae) lib(ertus) Isochrysus sibi et / Pompeiae Maximae conlibertae / suae feminae iucundissimae ex qua / nihil umquam dolui nisi cum decessit / et libertis libertabusque suis / h(oc) m(onumentum) h(eredem) n(on) s(equetur) CIL 06, 09438. Abuc]cius Asclas lictor III [decuriar]um qui Caesari et / [magist]ratibus apparent viat[ori decuri]ae Xviralis qui a[d iu]dic(ia) / [centumv]iralia praesunt gerul[us loci secu]ndi(?) quinquennalis / [collegii sc]abillariorum perpe[tuus ia seniorum immunis / Abuccio] Primo et Abuccio umis et Abucciae / libertae et e et sibi et / L Cleanthoibus decurias / qui Caesar ceteris libertis / meis libert eorum. CIL 06, 32294

One aspect highlighted by the variety of different *collegia* is a clear specialization of labor. Not all porters fulfilled the same function as one another. In addition to the *geruli and saccarii,* a variety existed which included *sabuarii*, men who specifically loaded ballast onto ships to stabilize the weight distribution, as well as *saccarii*, men who specialized in unloading grain ships. *Phalangarii* specifically carried amphorae off of the boats. Other groups included *stuppatores*-the caulkers, *restiones*- the ropemakers, *mensores frumentarii*- measured grain being unloaded, *horrearii*- warehouse workers, and *custodiarii*- warehouse guards. Such a use of specialized labor for thousands of porters makes it particularly feasible that comparative data from the early modern period could reveal further insights.

Indeed, it is probable that many aspects of porters remained relatively stable until the mid twentieth century and the advent of containerized shipping. First, there were large numbers of potential individuals seeking work both permanently and seasonally, which is known as employment and casual labor respectively. Second and more importantly, the methods that the porters used to unload vessels frequently matched those porters at Rome in that the sacks, crates, barrels, and individual pieces of cargo were taken from the ships' hold and then carried by hand down a gangplank to the quay. Admittedly, many of the ships in the nineteenth and twentieth century used a variety of winches and cranes to take cargo from the hold, but this was by no means the majority. Even in early twentieth century Manchester only five percent of dock workers were unloading goods by crane or winch, while the remainder of employees used other methods, such as manual unloading.[30] Even though some data from the early modern period concerning hiring practices and labor divisions for unloading is more hypothetical when compared to Rome, it is still instructive to understanding the potential organization for large scale labor.

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[30] .Simey, *The Dock Worker: An Analysis of Conditions at the Port of Manchester,* Liverpool, 1956, 30-31.

Due to the large population and the need for double loading and unloading, Rome must have employed a considerable number of porters. Despite the construction of *Portus* and Trajan's Harbor, a double loading and unloading process was still required, as the larger vessels could still not go up the Tiber to Rome. However, the harbor allowed Rome to utilize more local employment, a direct benefit to the Emperor who sought to alleviate frequent high unemployment at Rome. Additionally, the safety provided by the harbor allowed goods to be transferred from larger sea vessels to river skiffs or *caudicariae* without them having to move along the Italian coast, where they were more susceptible to Mediterranean weather. Aldrete estimated that 3,000 porters operated the harbors of Rome, but this figure seems too low when compared other historical ports as a percent of the population.[31] In 1888, Calcutta's population totaled 950,000. This included 7,327 dock workers, comprising .77% of the population.[32] Similarly, London, with a population of 4.5 million in 1890, had 22,000 porters who represented .48% of its population.[33] New York had 50,000 porters for .65% when it had a population of 7.6 million in 1950.[34] The average population percentage for the three locations equals .63%, thereby providing Rome with higher estimated range of 6,300 porters.

Although 6,300 porters is a more realistic estimate, the number was probably much higher. Due to Rome's double loading/unloading due to transferring cargo from arriving ship to quay, then from riverboat to Rome, it necessitated a heavy increase in the number of porters. Such a double

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[31] D. Mattingly and D.Potter, Life, Death, and Entertainment in the Roman Empire, Michigan, 1999, 157.

[32] T.Smith, Administration Report of the Commissioners for making Improvements in the Port of Calcutta, 1887-1888, Calcutta, 1888, 6.

[33] Green, Anna, *"The Work Process" in Dock Workers Volume II,* Vermont, 2000, 561.

[34] Levinson, 23

burden did not confront Calcutta, London, or New York. Also since Rome's harbor operated in a much more limited timeframe, roughly four months during the summer, as opposed to the aforementioned ports which operated nearly year round, the need for more laborers at a single point in time increased dramatically. Therefore, a more reasonable estimate of the number of porters working during the peak summer months would be 20,000 or higher. Such numbers are not unlikely considering the double loading and unloading process. Shanghai, which was eleven miles inland by river, had a similar situation of doubling loading and unloading with the use of riverboats. At the end of the nineteenth century, this city employed 20,000 dock workers for a population of 500,000.[35] During the winter the numbers would dramatically diminish, perhaps to around 5,000, since only riverboats were utilized.

It was likely that a large portion of porters operating at the harbors resided locally, providing a close and integrated community. For instance, in the early twentieth century, fifty-four percent of dock workers in Manchester resided within one mile of the harbor.[36] In Fremantle, Australia, half resided within two miles.[37] In early twentieth century Brooklyn, one in five residents of the district neighboring the port worked as a porter or trucker. Considering the close proximity of *Portus* to Ostia, about two miles, similar trends could have existed. It is likely that a core of the porters resided in Ostia, while many of the seasonal workers came from Rome to *Portus* during the summer. In addition, the generational continuity of porters was striking. In early twentieth century Antwerp,

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[35] L.Johnson, *"Dock Labour at Shanghai" in Dock Workers Volume I, Vermont, 2000,* 277.

[36] Levinson, 24.

[37] Ibid 25

fifty eight percent of all porters' sons pursued the family profession.[38] In pre-modern Manchester, that number reached a staggering seventy-five percent.[39]

In nearly all pre-industrial societies, a ritual called the shape-up occurred, whereby porters and longshoremen gathered to be recruited for a day's labors, typically at times right before dawn, at lunch time, and around six pm during the summer.[40] According to data from pre-modern India and early twentieth century Manchester, the foremen's gang would typically number around twenty five men.[41] The foremen usually hired five familiar veterans who would then help select individuals for the unloading squads.[42] Such a selection process indicated greater protectionism for established full time porters living locally in the area and related to the foreman or a veteran. However, it produced an unusually high number of casual seasonal workers who did not receive work. For instance, in early modern London, 22,000 thousand men sought work for 16,000 positions, providing roughly a seventy percent acceptance rate per day.[43] Worse still was Mombasa, in 1942 where 6,000 men sought work for eight hundred positions, thereby yielding a 13.33% acceptance rate for work.[44] Thus for dock workers, the need for regular porters to group together became a necessity. If they would attain neither enough work nor high enough wages under a casual labor system. By grouping together, they could choose to hire veterans who were friends, neighbors, or family

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[38] Ibid 24

[39] Ibid 24

[40] Ibid 21-22

[41] T.Simey, pp. 30-31 and Levinson, 21-22.

[42] Ibid. 31-32, 59-70

[43] Green, 561.

[44] Ibid

the hold.[48] They would grab the cargo, individually if light enough or in teams of two if heavy, and then bring the items quayside, at which point more junior members of the gang would take the cargo directly to storage. The practice of using only veterans in the hold is not unusual, as it provided a more secure safeguard against theft and the dropping or ruining of goods. Similar to Manchester, in early modern India, eight specialized men were on the hold while eleven were stationed quayside.[49] The other men performed functions such as tally clerks or crane operators if required.[50] Although some historians such as Rauh have suggested that ancient porters would line-up to pass goods along to each other, this seems unlikely compared to the historical precedent of other civilizations.[51] However, it may have been more possible to use such a method when unloading a grain ship where all the cargo was uniform.

The historical unloading times are comparable for pieces directly unloaded by hand. Unfortunately, the nature of the surviving evidence does not provide a detailed step-by-step instruction of the unloading process, but rather a summary of overall tonnage divided by time. From antiquity through the early nineteen sixties, each piece not unloaded by crane was brought down a single gangplank- assuming the ship was small or possessed the equivalent of a single hatch. One of the earliest records includes barrels of cod unloaded at 18th century Marseille.[52] A second

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[48] Simey, 30-31.

[49] D.Panda, 50.

[50] Ibid

[51] N.Rauh, *Merchant, Sailors & Pirates in the Roman World*. Gloucestershire, 2003, 152.

[52] P.Pomey and A.Tchernia, *Le Tonnage Maximum Des Navires De Commerce Romains,* Archaeonautica 2, (1978), 240.

source was mixed cargo in early twentieth century Manchester.[53] A last source from early twentieth century Hawaii cites men carrying sacks of sugars.[54] From this mixed cargo variety, they unloaded between twenty seven and thirty three tons a day for a rough average of thirty tons per day. Compared to modern container shipping, this process was notably slow. Although the porters of Rome were likely slightly smaller and more malnourished than their pre-modern counterparts it is likely that they could compensate slightly by picking the strongest men of the abundant labor pool, making possible a thirty ton daily average.

The common amount of weight handled by porters varied depending upon the distance traveled. For instance, in early modern Bombay a porter working with rice would typically carry 150 bags of rice per day with each bag weighing 168lbs.[55] To better utilize natural momentum and gravity, the same porter would "run" with the rice, often spending five hours a day running with the sacks around the quay. Unfortunately, it is not known common hours labored nor the distance carried by the porter with a sack of rice per trip, but one could imagine that with such a weight the distance must have been relatively short. Moreover, such heavy weights for porters were not uncommon. Data from eighteenth century England records 200 to 330 pounds were not uncommon for two men to carry. Likewise, information from 1920s San Francisco indicates that flour bags ranged from 100 to 150 pounds, coffee bags from 135 to 200 pounds, and sugar from 250 to 330 pounds.[56] However, if the porter traveled a farther distance, then the load he carried needed to be substantially reduced. One record indicates that a nineteenth century Englishman with a

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[53] Simey, 58.

[54] Goldblatt, *Men and Machines: A Story about Longshoring on the West Coast Waterfront.* San Francisco, 1963, 17.

[55] Green, 573.

[56] R.Cherney, *"Longshoremen of San Francisco Bay, 1849-1960" in Dock Workers Volume I, Vermont, 2000,* 110.

ninety pound load often traveled 12.4 miles per day, making for 6.2 miles with load and 6.2 miles without a burden.[57] The implications for Roman porters meant that heavy loads and long distances were probably not uncommon. Perhaps the best known comparable examples are amphorae jugs containing wine and olive oil that weighed roughly a hundred pounds commonly carried by two man teams.[58]

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[57] B.Cotterell and J.Kamminga, *Mechanics of Pre-Industrial Technology,* Cambridge, 1990, 194-196.

[58]G.Houston, *Ports in Perspective: Some Comparative Materials on Roman Merchant Ships and Ports.* American Journal of Archaeology, 92.4, 1988, 553-564.

IV. Capacity at Rome's Harbors

Harbor capacity, the amount of goods that can be safely imported and exported, entails several key aspects. Knowledge of the expected total tonnage of imports and exports is needed, as it allows one to determine theoretical scale of operations for both harbor size and labor needs. Next, an understanding of the duration of the safe sailing season, which determines the average number of days the harbor was open and thus could import goods is required. Furthermore, knowledge of the raw capacity in terms of the total numbers of ships the harbors could actually hold is needed. When all elements are combined, an idea of the theoretical maximum tonnage emerged. However, one must also consider all possible constraints and other theoretical needs of the harbor, such as the effect on the types of ships, bad weather, natural disaster, inefficiency within the harbor, and other potential problems. Once all elements are considered, a more realistic impression of actual harbor capacity emerges.

Imports are the first critical factor to understanding Rome's harbor capacity as it needed goods on a massive scale. In many ways, Rome was a consumer city since the amount of imports far outweighed exports. Rome could be one because by the end of the first century BC it could command all the excess resources of the Mediterranean for its growth. Provinces like North Africa and Egypt were able to pay tributary taxes in grain, thus further enabling the city to sustain itself.

Grain proved the most significant import. From the tribunate of Gaius Gracchus in the late 120s BC onwards, the Roman government provided monthly rations of grain to citizens at a subsidized rate. From the mid first century BC, the number of recipients became limited but they no longer had to pay.[59] In part due to the grain dole and in part due to tradition, the Roman diet derived roughly two-third of its calories from grain.[60] Olive oil was used frequently in conjunction with the bread produced from grain, thereby yielding another twenty percent of the caloric intake. Only about ten to fifteen percent of the average Roman diet consisted of meat, fruits, and vegetables. With this diet, Aldrete and Mattingly calculate that the average caloric intake per individual was about 2,326 calories per person.[61] This estimate must be reckoned as an average: an active male would generally require more, while children and women often required less.

The scale of imports required to sustain such a caloric intake for one million people became staggering. Aldrete and Mattingly estimate a minimum consumption of 237 kg of wheat per year for a total of 237,000 metric tons. Furthermore, after compensating for spoilage, and barley required for animals increases the estimate to 400,000 tons. Olive oil is estimated at twenty liters per person annually, yielding a total tonnage of 26,000. Wine is estimated at a hundred liters per person annually, for a total estimate of around 160,000

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[59] It is unlikely that the grain dole ever exceeded distributions of more than 250,000 individuals. See Suetonius, *Julius Caesar* 38 and *Augustus* 40.

[60] For discussion of diet in antiquity see P.Garnsey, *Food and Society in Classical Antiquity,* Cambridge, 1999, 12-40.

[61] For information concerning caloric intake and tons of key goods imported see [61] G.Aldrete and D.Mattingly, *"The Feeding of Imperial Rome" in Ancient Rome: The Archaeology of the Eternal City*, Oxford, 2000, 146-156.

metric tons. Therefore, even using the lower estimates for grain (237K instead of 400K), the minimum shipping requirement is 423,000 tons. However, using the higher estimate for grain consumption, as well as fifteen percent tonnage increase for oil and wine to account for potential losses at sea, a more realistic number of 604,600 emerges. Moreover, there are additional imports to consider, such as marble. One estimate in particular believes that 50,000 tons of marble were imported yearly.

We may also be sure that Rome did not limit itself to only four imports. Imports of slaves, timber, perfumes, ivory, weapons, statues, exotic animals, and pieces of art were amongst many of the varied items brought to Rome. Therefore, a safe estimate of imports for such luxury items may range close to 200,000 tons, or slightly less than a third of the combined aggregate of the other goods.

Bare minimum imports to sustain population:	***Realistic Core Imports***	***All Imports***
Wheat: 237,000	Wheat: 400,000	Wheat: 400,000
Olive Oil: 26,000	Olive Oil: 28,600	Olive Oil: 28,600
Wine: 160,000	Wine: 176,000	Wine: 176,000
	Marble: 50,000	Marble: 50,000
		Other 200,000
Total: 423,000	**Total: 654,600**	**Total: 854,600**

***All figures in metric tons.**

Even as an estimate, such numbers prove instructive as they can give indicators of the size of port needed. For comparison, when London was approaching a million people in

1790 it imported 917,000 tons, a figure not too far from Rome's estimate.[62] Admittedly, London was not a consumer city as its exports came close to the import total. The composition of food and luxury items would have been significantly different, but London still acts a valuable model to gauge the accuracy of the scale of imports.

According to Vegetius, an ancient logistics thinker, 100 days of relatively safe sailing during the summer, May 27th through September 14th, occurred annually in antiquity.[63] Even though he acknowledges that more months could be used, March through November, it was not ideal. Similarly, the Christian church officials in the late fourth century indicate that government cargoes are permitted to sail from April 13th through the October 15th.[64] For purposes of creating a model of imports, however, it is safer to use the 100 days of rather safe sailing as the point when the vast majority of vessels arrived at Rome since the opening days or even month of the sailing season would be spent traveling from a home port to Rome. For instance, the distance from Alexandria to Rome would take slightly less than a month if unfavorable wind conditions were present.[65] Furthermore, in a period without insurance, we should assume that merchants would attempt to minimize their risk

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[62] For tonnage of London imports see G.Jackson, *The History and Archaeology of Ports*, Kingswood. 1983, 31-32.

[63] Veg *Re.Mil* 4.39. *A die VI. Kal. Iunias usque in Arcturi ortum, id est in diem VIII. Decimum kal. Octobres, secura navigatio creditor…post hoc tempus usque in tertium idus Novembres incerta navigatio est…ex die…tertio idus Novembres usque in diem sextum idus Martias maria clauduntur."*

[64] *Cod, Theod. 13.9.3*

[65] L.Casson, *Ships and Seamanship in the Ancient World,* London, 1995, 289.

and not begin their initial voyage until conditions were rather favorable. Therefore, the safe estimate for the peak period of harbor usage would be the 100 days of summer.

Finally, the equation to calculate theoretical maximum harbor capacity is the rough number of days the harbor functioned (100) multiplied by the number of vessels that could fit into the harbor then multiplied by the unloading time.

Theoretical Maximum Harbor Capacity Equation:

Days harbor is open per annum X *ship capacity* X *Unloading Time= Maximum Capacity*

It is important to note that the last two elements needed to calculate the theoretical maximum harbor capacity of Rome's harbors occur above. In Section II, recent archaeological research suggest that the combined total for ship capacity of *Portus*, Trajan's Harbor, and Ostia came to 750 vessels. Similarly, the unloading time for a vessel by hand comes from section III on human labor. In that section, it was estimated that a porter gang could roughly unload a vessel at about thirty tons a day. Therefore, the formula with the inserted figures comes to:

100 Days per annum X *750 Vessels* X *30 tons per day per vessel = Maximum Capacity*

Answer:

2,250,000 Tons = Maximum Capacity

With over two million tons of harbor capacity it seemed that Rome had more than enough space and time to cover its estimated 850,000 tons of imports. However, this maximum capacity does not take into consideration several key constraints. Events such as heavy rains, flooding, fogs, ship to river skiff transfer, and administration time for docked boats all diminish the theoretical maximum. Such constraints or negative modifiers could quickly mount to the point where they could rather adversely affect the maximum capacity and therefore the ability to cover requisite imports.

Arguably, the reloading of vessels inside the harbor after they had unloaded their cargo used the greatest percentage of the excess tonnage. For instance, in the earlier comparison with London in 1790, when the city reached a population close to one million people they imported a little over 900,000 tons, but still exported roughly 750,000 tons, thereby utilizing a great portion of total harbor capacity. Even though Rome acted as a true consumer city in that it did not produce much in terms of exports, it still had some. Moreover, the grain vessels which occupied the largest percentage of the incoming fleet were filled with ballast after unloading to prevent them from capsizing on the return voyage. The *saburrarii* held this particular role of reloading these vessels with ballast. If one estimates that the 400,000 tons of grain ships were half filled with ballast to stabilize them on their return voyage, then perhaps an estimated 200,000 tons of ballast was needed. Additionally, most of the vessels carrying wine, oil, and other goods would seek to have some items to take back to their native port. Thus, for simplicity of argument, we could imagine that Rome exported slightly less than half of its total imports, namely about 400,000 tons.

One of the most important of the constraints affecting maximum capacity was the heavy rains and floods that Rome suffered. Aldrete suggests that from the first century BCE through the second century AD that Rome experienced a large flood once every twenty years, while suffering from extremely heavy rains once every four years.[66] These periods of flooding and heavy rains occurred predominantly in the winter through early spring when food reserves were naturally low. Heavy rain could cause an accumulation of moisture, causing stored grain to mold. Furthermore, it prevented the *codicariae* or river boats from functioning at full capacity as the heavy rains increased river current velocity, making their trip more tenuous, while at the same time difficult to keep the grain they were transporting dry. Floods caused more alarm. They could directly hit stores of grain, causing the grain there to mold. Additionally, floods would shut down river transport initially, preventing relief supplies from Ostia or Portus from reaching Rome. Flooding also dislocated people and killed beasts of burden, thus preventing normal transportation of goods from operating at full capacity. However, it is worth noting that the Romans built their warehouses to resist flooding to the best possible degree with narrow entrances, raised floors, and plenty of ventilation. Even so, if enough moisture accumulates in an area, mold will likely occur, causing food to spoil. A further effect of wet weather was the notorious "pea fog" or dense fog that struck Europe's harbors, even in the summer. Heavy fog so reduced visibility that it became too dangerous to handle goods on a dock, thus halting operations and reducing maximum capacity.

One of the key modifiers to maximum capacity were operations inside the harbor. In particular, the *codicariae* or riverboats caused the depletion of some of the importation

[66] Aldrete, 71-81.

capacity, since during the summer a large percentage probably pulled up to an incoming vessel quayside and used a gangplank to unload directly cargo from one vessel onto another, thereby taking up precious harbor space. Other minor factors included the towing and maneuvering of vessels within the harbors. Once vessels reached the entrance to the Portus and Trajan Harbor complex they needed to be pulled by tug boats to the quay.[67] Three different types of oar tugs were available, depending on the water depth and harbor region needed. Regardless of the type, the tugs' slow movement pulling the larger vessel generally caused traffic and occupied precious time within the harbor, thus reducing the potential maximum import tonnage. Similarly, just presenting papers to administration officials, talking to warehouse guards or *custodiarii,* or paying the 2.5% duty caused loss of time, since it is unlikely the unloading could begin until everything was cleared by officials. For instance, Rickman notes that when *amphorae* are unloaded off a ship three clerks were present.[68] The first clerk presented a token to the porter, while another raised his palm indicating the action, while the last wrote it down in a journal. This method was to prevent items from disappearing in route to the *horrea.* Thus, it is easily

[67] Image of porter conducting a direct ship to ship good transfer. Image from Ostia. See A.Pascolini, *Ostia: Return to an Ancient City,* Rome, 1979.

[68] G.Rickman, *Problems of Transport and Storage of Goods for Distribution,* Lecture presented at L"Ecole Francaise in Rome, 1998, 321

imagined that various types of officials involved quayside inevitably slowed down the efficiency of unloading goods.

Merchant vessels and riverboats both impacted capacity, but to an unknown degree. The style of the merchants' ships, with two masts or three, does not impact capacity, since all ships unloaded in a similar manner and docked at an oblique angle facing the quay. Rather, the important aspect was the size of the vessels. The larger vessels had faster processing time since regardless of size, they would require to be tugged and routed through dock administration. Casson has demonstrated that Rome employed a range of sea-bound vessels in regards to tonnage.[69] For instance, the Alexandrian grain shipper the *Isis* was exceptionally large at over 1,500 tons in capacity.[70] However, this size was the extreme rather than normal. Mattingly and Aldrete believe the bulk of the merchant fleet would have been around 250 tons.[71] Houston has shown that the majority of ships historically have been less than seventy tons until well after the Renaissance so to suggest Rome utilized 250 ton vessels would make it an historical anomaly.[72] Therefore, the distribution of the various sizes of ships remains unknown, and its impact on capacity should act as neither a positive nor negative constraint.

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[69] L.Casson, Lionel. *Ships and Seamanship in the Ancient World.* London, 1971, 183-188.

[70] Casson, 187.

[71] Aldrete and Mattingly, 154.

[72] For general treatment see G.Houston, *Ports in Perspective: Some Comparative Materials on Roman Merchant Ships and Ports.* American Journal of Archaeology, 92.4, 1988, 553-564.

River boats or *caudicariae* prove to be one of the great complexities of the Roman transportation system.[73] These vessels possessed a single mast towards the prow of the ship one which acted a tow line. Either Gangs of men known as *helcarii,* or oxen teams, then pulled the ships toward Rome. Mattingly and Aldrete suggest that it took up to three days for the trip.[74]

A three day trip for the fifteen miles from Portus to Rome on an eight hour work day meant an average pace of .91 miles per hour. Such a pace seems feasible when one considers that one towed vessel could not pass another in route as it would have to cross tow line in addition to having one boat move around another. However, it is imaginable that, with enough men towing a *caudicaria* it could have doubled the pace despite water resistance, thus making it possible to manage the trip in 1.5 days assuming low traffic volume. Such a pace might be needed if an emergency in Rome triggered the necessity for a rush supplies to be brought in from warehouses at *Portus*. The average size of a *caudicaria* is estimated at seventy tons.[75] Such tonnage resulted in an unloading time of two and a half days when one also adds time for docking and paperwork.

It is also important to emphasize that the *caudicariae* did not cause a bottleneck in the processing of goods to Rome and thereby no were further constraint to maximum capacity. For instance, if it is assumed that Rome distributed grain, oil, and wine equally amongst the three storage locations when they initially arrived, then the 3:3:1 warehouse

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[73] G,Aldrete and D.Mattingly, 148-149.

[74] Ibid
[75] Ibid

ratio suggests that 253,932 tons (42%) went to Rome immediately via riverboat upon unloading in the summer. Moreover, if one further reckons that the 200,000 tons of miscellaneous cargo also went to Rome, then the combined total for summer transport or peak traffic period equals 432,932 tons. Next, if one divided this amount by the hundred days of peak sailing, it yielded 4,539.32 tons per day transported by river. Since it took three days for a *caudicaria* to reach Rome, the twenty-two mile stretch of river is then divided by three for 7.33 miles or 38,719 feet for a subsection. At seventy tons capacity per *caudicaria,* this means that sixty-five *caudicariae* were present in each one-day subsection at a rough spacing of five hundred feet per vessel. This distance is plenty of space to prevent a bottleneck or river jam with a decent pace, although it meant a a slow and continuous line of river boats moving towards Rome in the summer. For an interesting point of comparison, Shanghai in mid nineteenth century when it had half Rome's population, continuously employed 13,000 boatmen to move supplies up and down the Yangzi River.[76] Rome had to have employed thousands to keep the *caudicariae* moving.

In summary, although Rome suffered from many negative modifiers it was unlikely when all three harbors operated that Rome suffered a shortfall of imports as a result. However, if one reviews Rome prior to the addition of Trajan's harbor, then the situation is different. Without Trajan's harbor, Rome only had 200,000 tons of excess capacity, at which point it then becomes conceivable for normal constraints to impact Rome's needed imports. In fact, if one keeps the estimated 400,000 tons of exports in addition to 850,000

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[76] L.Johnson, *"Dock Labour at Shanghai" in Dock Workers Volume I, Vermont, 2000,* 275.

tons of imports in the pre-Trajan harbor condition, then Rome went beyond capacity. Under such circumstances, the actual amount of imports is forced downwards, resulting in more risk of starvation and general unease.

V. What if a disaster occurred at Rome's Harbors?

It seems particularly useful to model the effects of some of the negative modifiers and potential disasters as they would have impacted Rome's most critical import: grain. Several models will be presented to simulate the effects of Rome importing grain under normal conditions; variable consideration for consumption, spoilage/theft, and events triggering a loss of reserves.

The fixed variable or the number that will remain constant for the initial tables will include the import of 400,000 tons of grain during the summer. As mentioned above, the significant excess capacity of all three harbors would negate the possibility of officials or docking problems reducing this number, so it will not change until the final model. The second fixed variable is the amount consumed. In the charts below, consumption is given at 23,916 per month. This combines the 237,000 tons of grain needed per annum to prevent starvation, plus 50,000 tons of grain used annually as animal fodder divided equally for twelve months. Spoilage is given at three percent a month to account for monthly losses due to mice, mold, birds, and theft.[77]

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[77] This is an estimated number. Unfortunately I could not find an ancient author who gave an estimated rate of loss. See G.Rickman in *Roman Granaries and Store Buildings,* Cambridge. 1971 presents the most thorough analysis for a general treatment of Roman *Horrea.* He presents potential problems such as moisture, theft, etc but does not give estimated loss rates. I am basing my decision upon consideration that most Roman granaries were built to prevent loss through moisture through elevated floors and ventilation, and to prevent theft through narrow doors and pathways, but some loss was inevitable.

The first model shows Rome under normal conditions without any major disaster affecting food stores. The subsequent models will then show the increasing effects of minor, medium, and large disaster, such as a flood or a wheat virus destroying a significant amount of the grain stores. The final graph will show the effect of reducing the amount of grain imports due to reduced capacity.

1. **Model One**- Rome with all three harbors active under normal conditions. The start point for all the graphs is June due to it being the first month that has enough imports to surpass consumption. Note the final reserves for May, as it indicates that Rome under normal importing conditions created a buffer in excess of 50,000 tons.

Month	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Imported	120,000	120,000	120,000	30,000	0	0
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal Loss at 3%	-3%	-3%	-3%	-3%	-3%	-3%
Total Reserves	93,201	183,607	271,300	269,063	237,792	207,460
Month	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Imported	0	0	0	0	0	10,000
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal Loss at 3%	-3%	-3%	-3%	-3%	-3%	-3%
Total Reserves	178,038	149,498	121,815	94,962	68,914	53,348

2. **Model Two**- Rome with all three harbors during a minor disaster adversely impacting grain stores in January. The disaster is set to fifteen percent, thus simulating the effect if a minor flood or fire in part of the grain stores in January. Note that even if such a disaster occurred, Rome still had grain stores in excess of thirty thousand tons.

Month	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Imported	120,000	120,000	120,000	30,000	0	0
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal loss	-3%	-3%	-3%	-3%	-3%	-3%
Minor Disaster Jan	0	0	0	0	0	0
Total Reserves	93,201	183,607	271,300	269,063	237,792	207,460
Month	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Imported	0	0	0	0	0	10,000
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal loss	-3%	-3%	-3%	-3%	-3%	-3%
Minor Disaster-15% Loss	0	-15%	0	0	0	0
Total Reserves	178,038	127,073	100,063	73,862	48,448	33,496

3. **Model Three**- Rome with a medium disaster. The next two models simulate the effects of a disaster such as a flood or fire destroying twenty-five percent of Rome's stored grain supply. One model indicates the conditions if it occurred in January, with the other for a July disaster. Note there is only a slight difference in the impact.

Month	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Imported	120,000	120,000	120,000	30,000	0	0
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal loss	-3%	-3%	-3%	-3%	-3%	-3%
Med Disaster Jan	0	0	0	0	0	0
Total Reserves	93,201	183,607	271,300	269,063	237,792	207,460
Month	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Imported	0	0	0	0	0	10,000
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal loss	-3%	-3%	-3%	-3%	-3%	-3%
Med Disaster Jan	0	-25%	0	0	0	0
Total Reserves	178,038	112,124	85,561	59,796	34,804	20,261

Month	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Imported	120,000	120,000	120,000	30,000	0	0
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal loss	-3%	-3%	-3%	-3%	-3%	-3%
Med Disaster July	0	0.75	0	0	0	0
Total Reserves	93,201	137,705	226,776	225,874	195,899	166,824
Month	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Imported	0	0	0	0	0	10,000
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal loss	-3%	-3%	-3%	-3%	-3%	-3%
Med Disaster July	0	0%	0	0	0	0
Total Reserves	138,620	111,263	84,727	58,986	34,018	19,499

4. Model Four- Rome with a major disaster. The final disaster is set to destroy 40% of the stores in January. Note that this is the final percentage of loss before Rome suffers starvation effects. However, this is a considerable margin. The granary ratio counter which is set at 3:3:1 tends to help minimize the problems of disaster. For instance, if all the *horrea* in Rome (not Ostia or Portus) were destroyed in a fire, such as the one that occurred in Nero's reign in 64 AD, then the city would only lose forty two percent of overall stores. Indeed, Tacitus records that Nero brought in reserves from Ostia and presumably *Portus* to provide relief.[78] It would have been devastating, but not to such an extent that the entire city would immediately starve.

Month	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Imported	120,000	120,000	120,000	30,000	0	0
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal loss	-3%	-3%	-3%	-3%	-3%	-3%
Minor Disaster Jan	0	0	0	0	0	0
Total Reserves	93,201	183,607	271,300	269,063	237,792	207,460
Month	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Imported	0	0	0	0	0	10,000
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal loss	-3%	-3%	-3%	-3%	-3%	-3%
Minor Disaster Jan	0	-40%	0	0	0	0
Total Reserves	178,038	89,699	63,809	38,697	14,337	408

[78] Tacitus, *Ann.* 15.39.9

Model Five- Rome with reduced grain imports without a disaster. This model represents conditions likely to have happened prior to the building of Trajan's harbor. Under such a condition, the harbor capacity is reduced due to mentioned negative modifiers above. Thus, grain is shown as reduced from 400,000 to 300,000 tons.[79] Note that under this new condition Rome actually suffers a loss worse than the impact of importing 400,000 tons and losing 40% of reserves.

Month	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Imported	90,000	90,000	90,000	20,000	0	0
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal loss	-3%	-3%	-3%	-3%	-3%	-3%
Total Reserves	64,101	126,280	186,593	177,197	148,682	121,023
Month	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Imported	0	0	0	0	0	6,666
consumed	-23,916	-23,916	-23,916	-23,916	-23,916	-23,916
Normal loss	-3%	-3%	-3%	-3%	-3%	-3%
Total Reserves	94,194	68,170	42,926	18,440	-5,312	-21,885

Rome obviously survived in its period of less capacity. It could have placed a priority emphasis on food imports and diminished non-necessities. Also, it is likely the city under the Emperor or Senate's direction frequently compensated by importing during periods of dangerous sailing.[80] Cassius Dio writes that Augustus during the winter famine of six AD write that he had gladiators and certain slaves sent out of the city, while giving imperial

[79] Trajan's harbor accounted for more than half of overall capacity that Rome, thus one may suggest I should reduce my estimate by 200,000 tons, but I believe that the Princepate reduced other imports at a faster rate than grain, therefore I have decided in this example to reduce import amount by 100,000 tons.

[80] For recorded instances of sailing in winter, see Seneca, *Brev. Vit. 18.5,* Suetonius, *Gaius 19; cf. 39.l;26.5; 31;* Cassius Dio *59.17.2,* Josephus, *Ant. lud.* 19.6, Aurelius Victor, Caes 4.3

officials, court jurists, and senators permission to leave the city to decrease food needs.[81] He also forbade banquets and celebrations, while regulating how much grain an individual could buy. In summary, there were possibilities to dealing with less capacity, but the solutions were not ideal; Rome needed the harbors.

[81] Cassius Dio *55.26.1* For further analysis of Rome's response to food crisis see Peter Garnsey, *Famine and Food Supply in the Graeco-Roman World: Responses to Risk and Crisis,* Cambridge, 1988, 219-225.

Part VII: Conclusion

Rome was an anomaly. Its immense and unusually large population required an extraordinary effort to maintain. More importantly, human labor and harbor capacity helped to determine its ability to sustain the population.

For the dock workers of Rome, their historical counterparts suggest a level of organization beyond what many scholars would normally assume. Moses Finley, perhaps the best known critic of Roman group organization, views *collegia* and consequently porters at a less developed stage than guilds or unions. He contends that they could not determine prices and set labor criteria in the manner that medieval guilds could and thus should be held in a lesser status.[82] However, the large numbers of porters and divisions of labor for specialized and often difficult work suggest otherwise. Moreover, the historical trends for protectionist activities against casual labor, their tendency to create social groups by living in close proximity, and the profession becoming hereditary implies a larger notion of social unity. Correspondingly, Gideon Sjoberg, a scholar writing roughly ten years before Finley, supports the idea that a 'guild' transcends the price determinate criteria and should also be

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[82] M.Finley, *The Ancient Economy, London, 1973,* 138.

valued along social lines.[83] Regardless of debate, porters formed an integral component of Roman society.

For the harbors, a different valuation occurs. Rome finally reduced the fear of negative constraints and variables such as bad weather, flooding, and administration impacting the harbor system with the completion of Trajan's harbor in 112 AD, but the problem was initially recognized 160 years before under Julius Caesar. Thus, it could be argued that the Rome was particularly slow in reacting to a known problem. Additionally, it was only with the completion of the newer harbor and its neighboring warehouses that it had a system that could more readily withstand the impact of disaster. Thus, in many ways harbor capacity created security for Rome.

Finally, the approach used in this paper could be readily applied to other harbors in antiquity by simply determining the known ship capacity in a harbor. The historical abundance of available porters, in addition to the relatively constant unloading times coupled with the known sailing season in antiquity provides for a transferable formula. With such knowledge it becomes easier to understand why some ports struggled and why others with excess capacity became more successful. Ultimately, capacity was a requisite for a thriving harbor and city.

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[83] G.Sjoberg. *The Preindustrial City: Past and Present,* New York, 1960, 187-192, 223.

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