Beyond labour figures

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Beyond Labour Figures:
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Abstract

A considerable amount of recent research on the economics of ancient construction has made use of architectural energetics, drawing primarily on nineteenth–century building manuals for useable labour constants. Such manuals are not the only source for understanding the Roman building economy, however, and indeed labour figures are only part of the equation. Focusing on stone carving, this paper highlights alternative comparative data, such as price–books, building and other accounts, and modern restoration projects, which can be used to better understand ancient practices. In particular, we explore a range of "hidden" costs beyond labour and materials, revealed in these sources but rarely accounted for in architectural energetics. These include variation in wages, profit on the part of workers, incidental costs for tools and accommodation, and contingencies for wastage and supply issues. By considering these factors we can better define the parameters for energetic studies concerning stone construction.

Keywords: architectural energetics, stoneworking, building manuals, price–books, tools

1. Introduction

In his *Practical Masonry: A Guide to the Art of Stone Cutting*, the fourth edition of which was published in 1903, William Purchase notes "there is perhaps a greater diversity of opinion as to the proper system to be adopted in estimating for stonework than is to be found in any other branch of the building trade."[1] John Rea echoes this sentiment: "there is considerable difference of opinion as to the description of various labours executed on stonework."[2] Pietro Paolo Drei, a third generation member of one of the loyal families of the Fabbrica of St. Peter's in Rome during the 17th century, noted the difficulty he faced in estimating the value of work completed by the sculptors who executed Gian Lorenzo Bernini's designs for The Four Rivers Fountain in Piazza Navona (1651) due to the fact that: "so many animals, trees, flowers and plants, all carved from a single mass of travertine supporting the obelisk required exceptional labour, labour that will not be appreciated by those who did not watch it take place".[3] For studies using architectural energetics to explore Roman architecture, for which reliable labour constants are the *sine qua non*, this is a problem: stoneworking, but also a range of other ancient building techniques, were (and remain) complicated, varied, and often highly regional. And indeed labour figures are only

[1] Purchase (1903: 134).
[2] Rea (1904: 150).
[3] Excerpt from the *Biblioteca Corsiniana*, ms. 167,31.B.14.fol.102, translated in Sarah McPhee (2008: 352).

part of the puzzle. The organisation of the building site and the workforce, the supply and sharpening of tools, the provision of space, and the arrangement of transport all impacted on the cost of building projects, as did other incidental costs, accidents, errors, changes in plan, and even poor weather. These are the awkward little things that can add up, and for which we have little or no ancient data.[4] While scholars employing architectural energetics have tended to focus on labour figures, material requirements, and transport costs, the data relating to these others factors are harder to track down, often more messy and anecdotal. 19th–century building manuals, which have proved vital for labour constants, do offer insights into these other costs, as do building accounts, company records, price–books, and even modern restoration projects. In this paper we draw on a range of datasets to consider these "hidden" costs and how they can be integrated into studies using architectural energetics. We focus, in particular, on the evidence for 1) variation in wages, 2) profit on the part of workers, 3) incidental costs, such as for tools and working spaces, and 4) necessary contingencies to cover fluctuations in supply costs and lost or damaged materials. We end by suggesting a set of totals that should be added to material and labour costs in studies of Roman architecture employing architectural energetics.

2. Source Materials

Before turning to the available datasets, a word on the source materials we use is necessary. In the absence of detailed Roman sources for the cost of architectural stonework, most scholars interested in this topic have responded by exploring cost not as a monetary figure but rather in terms of the labour it entailed.[5] This has involved using architectural energetics to "quantify past architectural remains in terms of the labor force involved" in order to reach a labour "cost" for the project.[6] For energetic studies looking at Roman architecture, the standard reference point for relevant labour constants has been the 19th–century building manual, *Manuale practico per l'estimazione dei lavori architettonici, stradali, idraulici e di fortificazione, per uso degli ingegneri ed architetti*, by Giovanni Pegoretti, originally published in two volumes in 1843 and 1844, with a second edition issued in the 1860s edited by Antonio Cantalupi.[7] Numerous comparable building manuals or price–books were published in Italy, France, Britain, and the United States throughout the 19th and early 20th

[4] For a discussion of what limited ancient evidence we have for a number of these issues, including building disasters, incompetent workers, and construction fraud, see John Oleson (2011).

[5] For costs of whole buildings recorded epigraphically, see Richard Duncan–Jones (1982: 64). Occasionally the costs of individual architectural elements are preserved, but this is rare, making any comparison difficult. For one example, *CIL* XIII 5416–5417, which refers to the cost of marble revetment for the baths at Mandeure (*Germania Superior*), see Séverine Blin (2012). On the general problems for the Roman period, see Janet DeLaine (2017: 16–17). The situation is different for the Greek world, of course, from which several sets of building accounts are preserved. For example, at Epidauros, inscriptions list the building accounts for four separate structures in the sanctuary and list expenditures and incomes; see Alison Burford (1969), and more recently, Sebastian Prignitz (2014).

[6] Elliot Abrams and Leah McCurdy (2019: 3). For a detailed review, see Dominik Maschek in this volume. For examples of scholarship exploring ancient stoneworking using an energetics–based methodology, see DeLaine (1997, 2001, 2015 and 2018), Paolo Barresi (2003), Begoña Soler (2012), Patrizio Pensabene *et al.* (2016), and Ben Russell and Justin Leidwanger (2021).

[7] Pegoretti (1843–1844; 1868–69). From a modern energetics perspective, the volume was first applied by Janet DeLaine for her book on the Baths of Caracalla (DeLaine 1997). She discovered the Pegoretti volumes during her period as a Junior Research Fellow at St John's College, Oxford. DeLaine's (1997) book, a revised version of her doctoral thesis (which had in contrast relied chiefly upon British architectural handbooks), made extensive use of Pegoretti and remains both a paradigm and paragon of Roman architectural energetics, shaping the pattern of such research and the adoption of Pegoretti as a source.

centuries.[8] Useful data of a similar sort can be found in the under–used architectural encyclopaedias, such as Joseph Gwilt's *Encyclopædia of Architecture* and Edward Cresy's *Encyclopaedia of Civil Engineering*, both of which provide labour constants for various construction tasks.[9]

One of the criticisms often levelled at architectural energetics when applied to Antiquity is the reliability of these sources.[10] This is difficult to gauge with certainty, but close correspondence between manuals suggests that Pegoretti was by no means an outlier.[11] Other studies have also shown that his totals are in the right "order of magnitude".[12] Indeed, there is a close correlation between the average labour figures for various stoneworking tasks recorded in historical manuals and those recorded by modern restoration projects, on which distinctly ancient objects (such as Ionic or Corinthian capitals) were (re–)produced.[13] We should, of course, not expect pinpoint accuracy because such a goal is unachievable: time–labour values can only ever be an "estimate of the scale of costs",[14] since they would have varied in reality depending on the skill of the individual workers and a range of other unquantifiable factors.[15] In the words of Richard Elsam, these manuals were "to provide for architects, surveyors and builders, the wherewithal to competently judge the difficulties in the execution of the works, as well as of the different qualities of the materials and the goodness of workmanship, and thus be enabled to discharge their respective duties with honour and integrity."[16] As noted in the preface to Pegoretti's first edition, detailed estimates made in advance of construction allowed architects, engineers, and their customers to predict the cost of projects, the benefits of or issues with certain design decisions, the quantities of materials and workers needed, and how long the whole thing might take, and then to make modifications to plans and seek out alternative solutions as required.[17]

Building manuals can be distinguished from so–called "price–books", like Rea's or Elsam's. Where the former give labour constants measured in man–hours (with some daily wages and certain standard prices for materials), the latter provide the going rates, in monetary values, for a similar range of building tasks (with only a few labour constants). Although price–books are concerned with costs rather than time, it is still possible to infer

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[8] These other sources, without being exhaustive, include from Italy: Luigi Ponza di San Martino (1841); Francesco Salmojraghi (1892); Alessandro Ricci (1895); from France: Joseph Morisot (1820–1824), Louis–Charles Boistard (1822), Claude–Jacques Toussaint (1834, with revised edition in 1853), Blottas (1839), Joseph Claudel and L. Laroque (1863), and Jean–Baptiste Rondelet (1867); from Britain: Richard Elsam (1825), William Young (1896), John Hurst (1905), Banister Fletcher (1888), George Stephenson (1890), and Rea (1904); and for the United States, James Gallier (1836 and 1883), Frank Vogdes (1985), and Frederick Hodgson (1904). On comparing these manuals for stoneworking, see Simon Barker and Russell (2012: 88–89). Pegoretti's work does seem to have been regarded as the industry standard in late 19th–century Italy; for references to it, see Salmojraghi (1892: 279); Ricci (1895). However, other countries produced equivalent volumes, such as Charles Mayes (1859, 1862), which evidently became the standard reference in Australia.

[9] Gwlit (1842); Cresy (1847).

[10] For the difficulties and problems, as well as a summary of recent developments, see DeLaine (2017).

[11] Pegoretti (1843: 8) quotes the following, mainly French, sources: Jean–Baptiste Anselin (1810), Hebert Gauthey (1832), Rondelet (1831), Toussaint (1834), Boistard (1822), Ponza (1841), Nicola Cavalieri San–Bertolo (1826–1827), Morisot (1820–1824), and Blottas (1839). French manuals were widely used in Italy in this period, and the sixth French edition of Rondelet's manual was translated into Italian in 1831 and quoted by Pegoretti.

[12] DeLaine (1997, 2001 and 2006); also Javier Domingo (2012, 2014a and 2014b).

[13] A series of examples are given in Barker and Russell (2012). For a similar test of the reliability and applicability for brick–laying, see DeLaine (1997: 295–296, n. 5).

[14] DeLaine (2017: 17).

[15] On this point, see Barker and Russell (2012: 86–89). For problems specifically related to marble, see Domingo (2012); DeLaine (2017).

[16] Elsam (1826: v).

[17] Pegoretti (1843: 7–8).

labour times using the wage rates they list. For example, James Gallier's *American Price–book* estimates the cost of producing an 11–foot tall fluted Doric column at $101.74.[18] Using a mason's wage of $1.62 per day (or 0.17 cents per hour),[19] this amounts to 63 person–days (or 600 person–hours, if ten–hour days) of labour (excluding quarrying and roughing–out). Price–books were first published in Britain during the late 1700s[20] and then rapidly expanded through the 1800s.[21] Peter Nicholson's 1825 *The Practical Builders' Perpetual Price–book* is credited in Gwilt's 1842 *Encyclopædia of Architecture* as a key example in the development of this genre within Britain. Gwilt noted that Nicholson was: "a gentleman to whom the architect as well as the practical man are more indebted than to any other author on this subject."[22]

While scholarly attention has focused on these manuals and price–books—formally published texts, in other words—accounts from historic building projects or company records have received much less attention. These document actual work completed and the sums paid for it rather than hypothetical sums; they give us a better sense, in sum, of the kinds of costs that had to be accounted for on real projects. Building accounts, in particular, survive in large numbers. In Britain, for example, nearly 1500 building accounts are recorded in the Public Record Office that detail royal works from the reigns of Henry III to Charles I (1216–1649).[23] Additional records include the Fabric Rolls of cathedrals, such as York and Exeter (to name only a few),[24] and building accounts in public archives or private possession[25] in Britain, France, and Italy.[26] Most of the relevant accounts date from the 17th to 19th centuries, but earlier examples can also be found. Alongside these accounts of actual building projects, we can set records from companies supplying such projects, such as quarries, tool–makers, or hauliers.

The level of detail and information recorded in these historic accounts varies over time and between project and/or organisation. Some provide just summaries and lists of total expenditure or selected expenses. Others provide detailed information about the quantities and costs of materials, their transport, and the number and wages of workmen. Occasionally, these accounts include weekly or monthly summaries of expenditure, including the amounts paid to (and the names of) the workmen employed and the cost of materials and tools. For a typical example of English accounts, we can turn to the journal of John Vady, who was clerk of works at Eton College near Windsor (founded in 1440 by King Henry VI).[27] In the entries for 1444–1445, for example, the name of every stonemason, carpenter, blacksmith, labourer, and other worker employed is listed along with the days of the week that each worked and the amount each worker was paid.[28]

The data provided in these accounts, however, needs to be treated with caution. They record expenditure, not estimates from which possible expenditure can be calculated. They also record the sums paid for the completion of certain tasks and not, or at least not typically,

[18] Gallier (1836: 23). The cost is for a column of the following size: 11 feet high, 18 inches diameter at the bottom, and 14 inches diameter at the top of the shaft; the capital is 9 in. deep and 1 foot 8 ½ inches square of abacus, with sunk neck and elliptic ends to the flutes. Assuming the block producing the shaft was 23 ft. 7 in^3.
[19] Gallier (1836: 16).
[20] William Pain (1774).
[21] Cf. Elsam (1825), Nicholson (1823), William Skyring (1845), and William Laxton (1839).
[22] Gwilt (1842: chap. 3, sec. 2347).
[23] *Public Record Office Lists and Indexes*, no. 35: 272–305. See Douglas Knoop and Gwilym Jones (1933a: 5) for the total number listed.
[24] James Raine (1859) for York Minster; Donald Findlay (1939), and Audrey Erskine (1981 and 1983) for Exeter Cathedral.
[25] Louis Salzman (1967).
[26] E.g., Christiane Klapish–Zuber (1969); Denis Cailleaux (1997); Nicoletta Marconi (2004).
[27] Knoop and Jones (1934a)
[28] Knoop and Jones (1934a).

the times that these tasks took; accounts focus on money, while manuals focus on time. Moreover, since the totals listed in accounts cover everything, they record not simply the cost of labour but also often the costs of materials, as well as a range of other expenses associated with projects. These caveats aside, building and other accounts provide an insight into the *real* experience of project managing and financing. They show how unpredictable this activity was and also offer insights into the range of items of expenditure above and beyond simply the labour and materials required to complete the project.

3. Wages

Labour figures from building manuals tell us how long certain tasks could be expected to take. They are necessarily estimates, since the skill of individual workers would have had a large impact on the completion time for a given task. To translate these labour times into expense, we need to consider the costs for the time of specific workers. In most cases, studies of ancient construction projects have used the daily rates provided by Diocletian's Edict of Maximum Prices (*Edictum de pretiis rerum venalium*) of AD 301 and translated these into appropriate monetary sums for other periods.[29] The Edict gives maximum daily wages and for stoneworking these consist of just three relevant sums: 60 *denarii* per day plus maintenance for a skilled marble–worker (*marmorarius*), probably a specialist in *opus sectile*; 50 *denarii* per day plus maintenance for a stone carver *(lapidarius structor);* and 25 *denarii* per day plus maintenance for a labourer *(operarius).*[30] Since it belongs to a distinctive historical and economic context, the totals from the Edict should be treated as highly approximate figures. In particular, we should be mindful here that both building manuals and accounts from later historical periods demonstrate that daily rates could vary quite considerably from period to period, from region to region, as well as between specialists.[31]

Dealing with these issues in reverse order, the building manuals as well as a range of accounts from later historical periods show that daily wages for workers could vary quite considerably, depending on their specialism. In Table 1, the base daily wages given by Ponza, Morisot, Rondelet, and Pegoretti (in the second edition) are provided. They show that the highest paid workers earned between two and three and a half times more than a basic labourer.

Accounts from the quarries of Carrara in Italy during the 1850s, furthermore, show that even within groups of specialists wages varied, presumably based on expertise or experience. Different workers also worked different hours. *Scultori* (sculptors), for instance, were paid 2.30–4.60 *lire* and *ornatiste* (ornament carvers) 2–3.50 *lire*, with both working eight–hour days. In contrast, a *sbozzatore* (rougher–outer), was paid 2.30–5 *lire* and a *scalpellino* (stone–cutter), 1.50–2.50 *lire*; both worked nine–hour days.[32] Here the highest paid worker probably earned closer to five times higher than that of a labourer (which is not listed), since we can expect labourers to have been paid less than the lowest end of the *scalpellino* scale (1.50 *lire*). We can see a similar wage gap between stonemasons and their servants or assistants in accounts from medieval Britain. An entry from 1480–1484 in the

[29] On the Edict, see Simon Corcoran and DeLaine (1994); Russell (2013: 33–36).
[30] Seth Bernard (2016: 81 f., Table 4.2); Miriam Groen–Vallinga and Laurens Tacoma (2016: 108 f., Appendix 1); Antonio Polichetti (2002: 220–221).
[31] The review of medieval building accounts by Knoop and Jones (1933b: 474–476) shows a great diversity in wage rates for stone workers. For example, nine masons at seven different rates of pay worked at Ely Cathedral in Cambridgeshire in 1359–1360, while there were 29 masons at five different rates of pay at York Minster in North Yorkshire in 1372. At Vale Royal Abbey in Cheshire in 1280 and Caernarvon Castle in Gwynedd (north–west Wales) in October 1304, a total of 51 masons were employed at 13 different rates of pay and 53 masons were employed at 17 different rates of pay, respectively.
[32] L. Maini (1852: 96).

building accounts of Kirby Muxloe Castle in Leicestershire records the wages of both "roughmasons" and "servants of the said masons".[33] The roughmasons are listed in three wage groups: W. Taillour, W. Wyso, and J. Paille were paid 18 pence (*d*.) for five days work; T. Sandur was paid 6*d.* for two days work; and J. Crosse was paid 6*d.* for three days work. The "servants" of these masons were paid 8*d.*, 4*d.*, and 4*d.*, respectively, for the same number of days work as their masters. The roughmasons, therefore, earned roughly double (and sometimes more) that of their assistants. The same ratio can be found in the Vale Royal Abbey accounts, with roughmasons earning double what their servants earned, and the highest level masons (below management level) earning more than three times this (Table 2).

The gap apparent in the medieval and 19th–century figures between the highest and lowest paid workers in the stoneworking industry only seems to narrow in the 20th century. Tables 3–6 show wages from the 1930s for different quarry workers active in three areas of the Livorno (Leghorn in English) region, in the area around Turin and in the area around Milan. A full range of specialists is again listed, many of them on different wages. However, the spread of wages is much narrower than in earlier periods, especially if we ignore the apprentices and children recorded in Turin and Milan (on which more below). What is more noticeable in these early 20th–century figures are the extent to which wages differ within the different quarry zones of Livorno, despite the close proximity of the quarries, and the fact that in the region of Turin hourly wages were different inside and beyond the quarry.

The Turin and Milan figures also offer some insight into the economic implications of using apprentices and indeed children. In Milan apprentices were paid less than half what carvers were paid, and indeed less than labourers, but no detail is given as to their experience. In Turin, apprentices were paid roughly half the wage of a second class marble "designer", but only after three years of work; prior to this they were either paid much less, perhaps closer to the sum children were paid, or were simply provided with accommodation and food. In Medieval Britain, these benefits were included alongside a small wage.[34] In 15th–century Venice, a qualified mason was paid 25 *soldi* per day (or about fifty ducats per year), while apprentices were paid between five and ten *soldi* per day, depending on age and training.[35] Similar wage differences are evident in medieval Britain, with apprentices of master masons sometimes paid as little as 33 per cent of the standard wage.[36] While apprentice's wages could sometimes be higher, in the order of 50+ per cent or 75+ per cent of the standard wage, it is unclear if these individuals were apprentice stonemasons or apprentice master masons.[37] Table 7 shows the wages paid to apprentices in Britain from various periods and areas. As can be seen, in Kent in1563 and in Wiltshire in 1604, apprentices were paid roughly half the

[33] Knoop and Jones (1933a: 70).

[34] This is clear from a number of Medieval building accounts, which show masons' apprentices provided with housing, food, and clothing in addition to being taught the trade of stone carving. Payments from the Vale Royal Abbey accounts record over a period of several years payment to "R. Winchecumbe and his apprentice", who received varying weekly wages of between 6 shilling (*s*.) 7*d*. and 4*s*. 10*d*. for the two. From this total, R. Winchecumbe paid out a wage to his apprentice, with the latter receiving 2*s*. 3*d*., then 2*s*. *d*., and later 2*s*. 9*d*. as he became more skilled. See Knoop and Jones (1934a: 33–34). In some cases it is clear that the apprentice received this payment in addition to food and clothing. In 1480, Walter Byse, apprentice to John Gare for eight years, received meat, drink, clothing and 3*d*. in wages in the first year of his apprenticeship, rising to 6*d*. in his second year, and so forth at a rate of 3*d*. a year, so that he received a wage 10*s*. after serving eight years. See Knoop and Jones (1934a: 33).

[35] Susan Connell (1988: 63–64).

[36] Knoop and Jones (1933a: 164–165).

[37] Knoop and Jones (1933a: 165) provide the caveat that it is unclear if these apprentices were training as stone–cutters and carvers or in the planning, design, and organization of building operations. Knoop and Jones suggest that the latter scenario would help to explain the relatively higher wages being paid, since these individuals would likely have been experienced stonemasons qualifying for "higher branches of masonry … rather than 'raw recruits' learning the skill of stoneworking."

wage of a master freemason. The figures from Kendal in 1710 add the additional detail that wages of 5*d.* were paid to apprentices with less than one years experience and 7*d.* for those with between one and three years experience. The former category was less than half that of a master mason's wage (12*d.*) or exactly half that of a roughmason's wage (10*d.*). The wage for more experienced apprentices was just over half that of a master mason and about two-thirds that of a roughmason. If apprentices or junior carvers undertook the initial stages of roughing out for architectural work, for example, then the cost ratios could look very different to those presented by simply applying basic figures for labour costs in the building manuals.[38]

Finally, while the modern concept of overtime does not seem to have existed in Antiquity, we might expect premiums to be added to jobs that needed to be completed in a rush. In 1932, higher wages were noted for overtime work at various quarries in Italy: near Rome, 20 per cent over the regular rate was paid for the first two hours of overtime and 25 per cent for each succeeding hour; 14 per cent extra was added for two hours of overtime in the Milan district; ten to 15 per cent extra was added according to the number of hours of overtime in the Livorno district; and, 20 per cent extra was added for the first two hours of overtime and 30 per cent thereafter for marble workers in the Turin district.[39]

4. Profit

The various wages listed in the section above consist of the sums paid to workers to cover their labour. On most historical building projects, however, various sums were usually added to these wages to cover the costs of employing workers, arranging contracts, paying supervisors and other managers, the fees of which were not accounted for by the daily wages of actual workers. These sums are typically described as "profit" and they effectively oiled the wheels of on–site human resourcing. In practice, most architects or project managers, especially on larger projects, would have contracted out the task of hiring and managing workers, as well as supplying materials, and it was the contractors they appointed who would have mostly consumed these profits.[40]

An example of just such an individual from a later period is John Prophete, who supplied stone for Westminster Palace in London and Windsor Castle in Berkshire during the 14th century. It seems that Prophete was also an entrepreneur, who owned or leased quarries, paid the wages of quarrymen and stone–cutters, and sold both worked and unworked stone.[41] Master Thomas of Weldon, who supplied stone for Rockingham Castle in Northamptonshire, also appears to have employed a number of stone–cutters, layers, quarrymen, and labourers.[42] Similarly, an agreement from 1434 by a mason to build the nave of Fotheringay Church in Northamptonshire records that all materials were to be provided by him and he was to be paid a total of £300, by instalments.[43] Out of this, he was to pay his men's wages, presumably making a profit along the way. Indeed there was an expectation of profit on the part of such individuals. For example, an agreement by a mason, dated to 1511, for building the stone vault of the Lady Chapel of St. George's Chapel at Windsor Castle states that "he is to provide all materials and to complete the work within 2¾ years, for a total of £326, 13*s*. 4*d.*". The contract further adds that "if at the end of the work he swears that he has not made £20

[38] Dietrich Boschung and Michael Pfanner (1988, 13–15, fig. 7) assume the presence of both master carvers and assistants in the statue–carving process, with assistants undertaking all the carving until the final stages. This would entail the assistant carrying out the bulk of the work.
[39] From "Wages and Hours of Labor", in *Monthly Labor Review* 34, no. 5, 1932: 1173.
[40] On this aspect of Roman building projects, Duncan-Jones (1982: 75–76); Rabun Taylor (2003: 16–17); Ricardo Mar (2008); Russell (2013: 202–207).
[41] Knoop and Jones (1933a: 10).
[42] Knoop and Jones (1993a: 10).
[43] Salzman (1967: 505–509, Appendix B, no. 66).

profit on the contract, he shall have another £11, 13*s*. 4*d*."[44] This £20 is equivalent to about 6 per cent of the total contract.

Larger contracts or bigger projects would have offered more scope for profit. During the 17th century in Britain, for example, payments for work were organised in a number of ways.[45] One approach employed for the rebuilding of St Paul's Cathedral in London was work done "by Great", where mason–contractors agreed to undertake a set piece of work for a fixed price.[46] This was typically either the whole building or part of the building. In the case of the rebuilding of St Paul's, Campbell has noted that this method sometimes ended with contractors getting themselves into financial trouble, because they had wrongly estimated the time the work would take, thereby jeopardizing the whole project.[47] As a result, more reliable contractors often charged a premium for working "by Great", and, as Christopher Wren remarked, "made great profit by it".[48] The sum that the contractors would have quoted in this arrangement would have to have covered their own wages, the wages of any workers they engaged, and a profit of some sort.

If we turn to the Roman period, we can find some evidence from construction contracts for similar practices. A 2nd–century papyrus from Oxyrhynchus in Egypt provides an example for the supply of stone. It records a contract between Asklas and Appollonios, two stone–cutters, who agreed to supply stone to Antonia Asklepias for the building of a house, at a price of 39 *drachmas* (*dr.*).[49] The contract included a variety of prices for 292 different sizes and types of blocks. We cannot assess how much profit these workers were making on these blocks, since we do not how long they had to produce them or whether they needed to pay someone else for the raw materials. However, it is striking that they also demand four *dr.* per day and food should their services be required by the builders (presumably at the building site) after they had supplied the stone. This daily wage is roughly three to four times the average wage for workers recorded in the Nile Valley in this period and double that received by quarrymen at the imperial quarries at Mons Claudianus.[50] This

[44] Salzman (1967: 562–563, Appendix B, no. 106).
[45] See James Campbell (2005: 33 –339), for an overview of the methods of contracting used during the 17th century.
[46] Campbell (2009: 298–299), on the methods of payment and contracting used for rebuilding St Paul's Cathedral.
[47] Campbell (2009: 298).
[48] Campbell (2009: 300, quoting WS V: 20). In connection to his study of the Master Carpenter at St Paul's, Campbell (2005: 332–336) estimated that he would have likely made somewhere between 20 and 40 per cent profit. In this case, he was paid "by Day", but importantly, he claimed that if had been paid either "by Measure" or "by Great" that he could have made higher profits for his work.
[49] *P.Oxy* III.498: "To Antonia Asklepias, also called Kyria, from Asklas, son of Alexandros, and Apollonios, son of Amois and Tauris, both from Oxyrhynchus. We undertake to cut the squared building stones, which are to be transported by camel from the northern quarry for your house, Antonia, in the quarter of Pammenes' Garden, at the following rate of payment: the outer squared camel stones at four *drachmas* for 16, the inner ones at four *drachmas* for 30, the *antiblemata* at three *drachmas* for 100 squared camel stones, oblong corner–stones at eight *drachmas* for 16 outer squared camel stones and at eight *drachmas* for 30 inner ones, axe–hewn squared camel stones at four *drachmas* for 50 and axe–hewn squared camel corner–stones at eight *drachmas* for 50. All of the previously mentioned stones we will cut, but no ornamentation will be expected of us. Each of us will also receive for each day that he works one loaf of bread and *'prosphagion'*. If the builders need assistance from the stone–cutters, we or one of us will assist them, each man receiving four *drachmas* as wages for each day's assistance and each of us likewise one loaf of bread and *'prosphagion'* for each day. Until the 22nd of the present month of Epeiph you have the right to transfer to others this contract for cutting the previously mentioned squared camel stones from the northern quarry.... The agreement is valid.... Year...." Translation by Allan Johnson (1936: 477–478, Nr. 304).
[50] Hans–Joachim Drexhage (1991); Cristina Serafino (2009: 47); Russell (2018: 737–738). See also, Alfred Hirt in this volume.

would seem to indicate that in this part of the contract at least, Asklas and Appollonios were making a substantial profit.

Evidence from later periods certainly shows that specialists working at the very high–end of construction projects could make substantial profits. The contractors who worked on the rebuilding of St Paul's Cathedral in London are cases in point. James Campbell has calculated that Edward Strong, the Master Mason on this project, was paid £690 for the work of 65 men over a period of 66 working days in September 1694.[51] If we assume a typical daily rate of 2*s.* per worker, a total of £6 12*s.* would have been paid to the workers over the 66 days, meaning a potential profit for Strong of 37 per cent of the total payment.[52] If the mason–contractors on the same project made a similar level of profit, their earnings would have been substantial (Table 8). Moreover, these were not the only projects undertaken by these individuals, and so these profits were only a portion of their overall income. The similar profitability of stonework in the ancient world is suggested by a series of inscriptions from tombs found in Phrygia, which testify to the wealth of individual stonemasons.[53] Indeed epigraphic evidence does show that Roman stoneworkers sometimes achieved both wealth and, in some cases, high status through their work.[54]

5. Incidental Costs

In addition to sums to cover the kind of profits outlined above, various historical sources offer a range of insights into the incidental costs associated with stoneworking beyond simply employing workers. Here we focus on two: tools, their purchase and maintenance, and the provision of accommodation or workshop space.

5.1 Tools

Historical building accounts show that it was common for the project itself to fund the purchase of tools and their maintenance, expenses which could add up to considerable sums. At Vale Royal Abbey in Cheshire, the building accounts from 1278–1280 record expenses for "the purchase of 24 hatchets for the masons at 5*d.* each and 30 hatchets for the masons at 4½*d.* each, as well as hammers, wedges, picks, etc. purchased for use in the quarry".[55] Considering that a smith's wage in the late 13th century was 2*s.* 8*d.* per week,[56] this is the equivalent to ten weeks of labour (or 21*s.* 3*d.*) for the purchase of tools alone. Further costs are recorded in other accounts.[57]

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[51] Campbell (2009: 305) used the number of workers detailed in Knoop and Jones (1935: 73–77) and payments from the WS XIV: 137.
[52] Campbell (2009: 305).
[53] Marc Waelkens (1986: nos. 417, 471, 486, 501, 502); Josef Strubbe (1997: no. 256); Reinhold Merkelach and Stauber (2001: 200, no. 16/22/05).
[54] For more detail, see Russell (2020: 254–258). On the social position of craftsmen involved in the stone and marble trades generally, see Krešimir Bosnić and Branko Matulić (2018).
[55] Knoop and Jones (1933a: 62).
[56] Salzman (1967: 70).
[57] A further payment is recorded in the Vale Royal Abbey accounts for February, 1277–1278 under "necessary expenses", which show that a payment was made to "Alexander de Norton for six 'pycons' (picks?) for the quarry, 2*s*. 3*d*. at 4½*d*. each; for eight 'howis' (hoes?), 2*s*. at 3*d*. each' for ten 'bechis' and 'triwlis' (trowels?), 15*d*. at 1½*d*. each" (Knoop and Jones 1934a: 16). In the building accounts of 1447 for Sheffield Castle, 13*d.* was paid for making one mallet, one stone–axe, two picks, and six iron wedges for use in the quarry for breaking and lifting stones (Knoop and Jones 1933a: 65). In addition, the accounts from Westminster Palace from 1532 record that 8*d.* and 16*d* were paid for "stone sawis for masons" and "a fyle for the said sawis", respectively (Salzman 1967: 330).

The costs of repairing and sharpening tools—on–going rather than one–off costs—were also handled in a variety of ways on different projects. On the Vale Royal Abbey project described above, smithies were erected at both the quarry at Edisbury and the abbey to maintain the tools used by both the quarry workers and masons working on–site. These were paid out of the project's accounts. Each smithy had six workers: a smith and his labourer (sometimes two smiths and two labourers), a charcoal burner, a labourer to work the bellows, a striker, and a further person to bring masons' tools back–and–forth to the smithy to be repaired.[58] Between 1278 and 1280, an average of seven workers worked at the smithies on the building site compared to 40 masons and 15 quarrymen, a ratio of roughly 1:8.[59] We should remember here that the ratio between those involved in tool sharpening and stoneworking in the granodiorite quarries at Mons Claudianus in the Roman period was about 1:4.[60] This discrepancy relates to the hardness of the stone.

Another solution to dealing with tool sharpening and maintenance is shown in the accounts of Kirby Muxloe Castle in Leicestershire, where a forge was erected in 1481. Here the smiths were paid by the number of tools sharpened, a total of 2*d.* per dozen.[61] Between August 1481 and November 1484, 46 entries are included in the accounts for a total of 318.5 dozen (3,822) tools. In this period, there were 173 working weeks, and so an average of 22 tools were sharpened per week. If we accept an average of four masons working each week, this would equate to 5.4 axes and chisels sharpened per week for each mason or roughly one per day.[62] These figures also demonstrate the relative expense of tool–sharpening compared to the wages paid to the masons. The wages of each mason was 3*s.* per week in summer and 2*s.* 6*d.* in winter. The 1*d.* paid to the smith each week per mason for repairing tools is equivalent to just over 3-4 per cent of their wage bill, depending on the season. Again, the stone being worked here was quite soft and indeed in India it has been observed that carvers of the considerably harder granodiorite could sometimes blunt as many as six chisels in a single hour of carving, which would have had serious implications when it came to the provisions of metal–workers (if six chisels per day had needed repairing at Kirby Muxloe in the 15th century, this would have amounted to 18–24 per cent of a mason's weekly wage).[63] Granodiorite is a much harder material than most of the stones used in British building but Knoop and Jones also note that smithies were more important at quarries than building sites due to the fact that quarrying, more than the dressing of stone, blunted the tools. They point to the fact that projects that included little quarrying—such as Eton College, where much of the stone was purchased rather than directly quarried—had relatively few smithies or payments for tool maintenance compared to Vale Royal Abbey and Caernarvon Castle in Wales (completed 1330).[64]

During the Medieval period, it seems to have been generally assumed that tools would be maintained on site and that this would be paid for out of the project budget. When this was not the case and masons were expected to pay for the upkeep of their own tools, this fact was explicitly stated. In 1350, the Wage Regulations issued by the City of London, for example,

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[58] Knoop and Jones (1933a: 63). The building accounts also include some of the costs of setting up the smith: two large bellows at 7*s*. 8*d*., two small bellows, one at 2*s*. and one 18*d*., two hammers at 10*d*., three hammers at 12*d*., and three pincers at 12*d*. See Knoop and Jones (1934a: 16).

[59] Knoop and Jones (1933a: 63).

[60] Russell (2018: 734).

[61] Knoop and Jones (1933a: 64).

[62] Knoop and Jones (1933a: 64–65) calculated the figure of 5.4 taking the total of 3,822 tools being sharpened during the 706 mason–weeks worked between May 1841 and November 1484 and diving it by the average number of masons including apprentices working each week, excluding the master mason. If the latter is included, the figure drops to 5.15 per mason-week.

[63] Pers. comm. Stephen Cox.

[64] Knoop and Jones (1933a: 63).

included the following statement: "In the first place, that the masons … shall take no more by the working day than 6*d.* … And for the making or mending of their implements they shall take nothing"; masons, in other words, were expected to pay for their own tools.[65] In some later periods, workers had sums extracted from their wages to cover the maintenance of their tools. Bill Mackie, for example, noted that his grandfather, a driller at Rubislaw Quarry in Aberdeen in the earth 20th century, had money withheld from his wages (between 2*s.* and 2*s.* 6*d.* a fortnight) to pay for the repair and sharpening of his tools.[66] In modern Carrara the same kind of system still operates, with blacksmiths moving from workshop to workshop, collecting tools that need sharpening, repair, or altering.[67] Insight into this system (and the dissatisfaction the masons sometimes had with the end result) can be seen from the mid 1950s, when Fred Cargill related witnessing the blacksmith pushing his handcart up to Kincorth, near Aberdeen, where masons were constructing a housing estate:

> "Lamont the blacksmith came with his handcart with big wheels, from Ashgrove Lane. He had a bag of sharps and took away your blanks, every few days. He was a slightly built wee chap and he pushed this big barrow. He had a squeaky voice. He used to come on to the site and say 'well boys how are the tools today'. We used to say just absolute shite, too hard, too brittle. He would say, okay, I'll let them know. Next day we would say too soft, just mushrooming. We would never say they were good. The tools didn't stand up to much, especially the puncheon, thumped with the 3 ½ pound hammer. The forge had rows and rows of puncheons being tempered. He took away their blunt tools and brought back sharpened ones he had collected a few days before. Tungsten was coming in at that time. It was too hard, it just burst. It is better now."[68]

5.2 Accommodation and Workshops

In addition to tools, a major incidental cost associated with the workforce on building projects related to the provision of workshop space and sometimes accommodation. The most basic form of workshop was a temporary shaded outdoor space; however, it is equally possible that temporary wooden structures were also built to accommodate workers. Unfortunately, both forms of temporary workspace are difficult to identify archaeologically except by the presence of noticeable layers of marble chippings and dust.[69]

We can get a sense of how such temporary workspaces may have looked by turning to "The Stonemason's Yard" by Canaletto (1697–1768), which was painted *c.* 1725 and is now in the National Gallery in London (Figure 1). The painting depicts a temporary stonemason's yard situated in an open space known as the Campo San Vidal beside the Grand Canal in Venice, Italy. In the painting, several masons can be seen at work carving blocks for the reconstruction of the nearby church of San Vidal. A similar wooden structure, open along one side, with blocks set up on wooden workbenches, was erected for the stonemasons currently working to restore York Minster (Figure 2). The sheds used for stonework during the 19th and 20th century at the granite–yards and quarries around Aberdeen were also broadly similar. A description from an investigation into phthisis (tuberculosis) among granite

[65] Knoop and Jones (1933a: 66).
[66] Jim Fiddes (2019).
[67] Will Wootton *et al.* (2013: 2).
[68] Fiddes (2019).
[69] On this point, see Amanda Claridge (2014). In Rome, such workspaces are suggested by thick deposits of marble debris, unworked quarry blocks, and unfinished sculpture in the area of the western Campus Martius, see Martin Maischberger (1997: 108–156).

workers carried out in 1876 by Dr. R. Beveridge from Aberdeen Infirmary described the working facilities as follows:

> "The mason works in long, narrow sheds, completely open on one side; near the open side, he places the stone, and works his face towards the light and air, and stopping over his work. He is, therefore, practically in the open air, the shed serving simply to protect him from wet; the dust is almost entirely above and behind him; while the muscular exertion necessary to wield his heavy tools is such as to keep him physically warm to resist variations of external temperature".[70]

In 1891, Charles Macdonald was the first to build a completely enclosed workshop for his workers. Macdonald's building was built of wood with a slated roof and ample air space; it housed 120 stonecutters and afforded them "complete shelter in all kinds of weather".[71] Sometimes roofed spaces had to be created at relatively short notice. The accounts of St Paul's cathedral in London, dating to the 17th and 18th centuries, show that special sheds had to be constructed by the carpenters in which to store the Reigate stone, so that it would not weather before use. Labourers were paid extra to collect the relevant blocks of stone and store them in these sheds,[72] as transport of stone by road for St Paul's could only be guaranteed between March and November due to the weather.

The financial implications for the provision of workshop space and accommodation for stonemasons are clearly visible in building accounts, and much of this cost of course needed to come early on in the project. For example, early entries in the Vale Royal accounts for 1278 include payments to "carpenters for making the *logias* [lodges] and *mansions* [dwelling houses] of the masons and other workmen, the smiths' forges at the quarry of Edisburi [Edisbury], and the site of the monastery [Vale Royal Abbey]", along with masons' workshops.[73] Similarly, a vacant piece of land was given to William of Cleve, clerk of works at Westminster Palace, London, in 1444, for the purpose of constructing worker accommodation and stores, such as the "tymber–hawe" and "trasiers" for the stone–cutters.[74] At Dover in 1536, in order to save time a couple of old "hales", or tents, were sought as workspace and dining areas in bad weather for the roughly 460 men so that they would not have to go into the town.[75] The construction of a wall at Westminster Hall in 1395, required the king "to find the lodgings for the masons and their mates during all the time they shall be occupied about the said work".[76] Lodging was also provided at quarries, such as at

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[70] Fiddes (2019).
[71] Fiddes (2019).
[72] Campbell (2013: 40); WS XIII: 156, 178, and 197 for details of the payments.
[73] Knoop and Jones (1934a: 16–17) note the following payments: In January 1277–1278, a total of 45*s*. was paid to six carpenters for "working and making huts (*logias*) and dwelling houses (*mansions*) for the masons and other workmen" and for "dwelling places where the master (*magister*) may received masons" as well as masons' workshops and other dwelling places. In April 1278, two payments are recorded. Firstly, six carters were paid 24*s*. "for carrying the boards and timber for making dwelling houses (*mansionibus*)", and secondly, 20 diggers were paid for six weeks work for "enclosing and ditching the places where the were making the dwellings of the masons and others". In May, 1278, 40*s*. wages were paid to plasterers "making and plastering the houses and other dwellings places in the site of the Abbey". The following year in April 1279, four carpenters received wages for "working on the masons' workshop". In June of the same year, a boarder and his fellows were paid 28*s*. "for making 14,000 boards" for the new masons' workshop. In addition, daily wages were paid to various carpenters "felling tree for timber and preparing them there in the wood with their axes", as well as daily wages and piece rates to sawyers for timber.
[74] Salzman (1967: 39).
[75] Salzman (1967: 39).
[76] Salzman (1967: 39).

Huddleton, used in the construction of York Minster, and Sandgate in Kent, used for the construction of Sandgate castle.[77]

It should be remembered that some accommodation for workers was necessarily large and therefore represented a substantial cost. At York Minster, the old lodge housed 20 masons with a second lodge erected in 1412 that housed 12 masons.[78] To put the erection of a lodge to accommodate the masons working at Vale Royal Abbey in some kind of context, we can refer to the cost already noted above of £4 16*s.* over two years, which did not even account for all of the costs related to these structures. Knoop and Jones suggest that by the end of the first two years, three lodges had been built to accommodate the average number of masons working on the project at that time (*c.* 41–51 masons), with an average of 17 masons accommodated in each building.[79] A fourth lodge seems to have been added by mid-1280. Two sets of payments in April 1280 record some of the costs related to its construction. Firstly, "Nicholas the boarder with his fellows" was paid 20*s*. "for making 1000 boards for the new masons' workshop and for others needed" and a further 40*s*. for making 2000 boards "for covering the masons' workshop and other houses".[80] In this same month, William le Daubour and his labourers were paid 34*s*. for "plastering a certain workshop near the site of the monastery and covering certain houses with turves".[81] The total, £4 14*s* was equal to about 3½ weeks of a stonemason's wage, assuming a wage of 27*d.* per week.[82] Likewise, in 1448–1449 at Vale Royal Abbey, a hall "60 feet long and 18 feet broad with convenient height" was built as masons' accommodation at a cost of £9 paid to two carpenters (assuming a average wage of 6*d.* per day for a skilled labourer this period equal to roughly 300 days of work).[83] Maintaining these structures could also add considerable cost to a project. The repair of two lodges at Westminster Abbey, London, in 1413, for example, cost 26*s.* 8*d.*[84] The importance of accommodation is evident in by–law VII, agreed between the Master Masons' Association and the Operatives Union in 1880 in Scotland, which stated that "sufficient shed accommodation be provided to hewers where practical".[85]

How projects dealt with these costs seems to have varied. Workers at the granite quarries in north–east Scotland were provided housing, but rent was deducted from their wages. We hear from an 1869 advertisement for the leasing of granite quarries at Cove that there were labourer's cottages "beside and in the neighbourhood of the quarries which are chiefly tenanted by the quarry men".[86] In a contract dated to 1457 for Corpus Christi College in Cambridge, however, a choice of arrangements is offered. The mason was either to be paid at a rate per rod (apparently equal to the rate he had been paid at Peterhouse College in Cambridge),[87] or else, 40*s.* in total for the whole project.[88] In the latter arrangement, the college provided lodgings for four men and the right of using the college kitchen to cook their

[77] Knoop and Jones (1933a: 76).
[78] Knoop and Jones (193a3: 57).
[79] Knoop and Jones (1933a: 57).
[80] Knoop and Jones (1934a: 17).
[81] Knoop and Jones (1934a: 17).
[82] For a discussion of masons' wages at Vale Royal Abbey, see Knoop and Jones (1934a: 18–19). Masons were paid different rates in summer and winter "on account of the shorter days", with some receiving 30*d*. a week in summer, reduced to 25*d*. in winter (these are highest wages paid to three workers in total). The average seems to have been 27*d*., reduced to 23*d*., with the lowest paid 12*d*. or less. It is possible that the highest paid were overseers supervising the cutters or hewerrs at 28*d*., 27*d*., 26*d*., and 24*d*., but this is far from certain, since the proportion paid compared to the other does not seem correct.
[83] Salzman (1967: 77).
[84] Knoop and Jones (1933a: 59).
[85] Fiddes (2019).
[86] Fiddes (2019).
[87] A *rod* is an old English measurement of length equal to roughly 5 m (or 16.5 feet).
[88] Salzman (1967: 531–532, Appendix B, no. 81).

food. The mason took the latter option but also asked for the help of two of the college workmen in digging foundations.

Lodgings were often also used to store tools. For instance, at York Minster, the Fabric Rolls lists 69 stone–axes, 96 iron chisels, 24 mallets, one compass, and two tracing boards, among other tools stored in the masons' lodge.[89] These tools were expensive items and Ricci even suggests that for marble–working the cost of supervision and security, to ensure that both valuable raw materials and tools are not stolen, needs to be factored in to any accounting.[90]

6. Contingencies

In her 1860 book, *The Marble–Workers' Manual Designed for the Use of the Marble–Workers, Builders, and Owners of Houses,* Mary L. Booth lists a range of factors that could increase or decrease the cost of building, many of which were unpredictable: the talent and/or fame of the specialists involved, the "scarcity or abundance" of a particular material at the time the work was undertaken, accidents on site, and alterations by the client.[91] She goes so far as to state that "it is impossible to indicate probable prices, since the price of today might be changed in a month or a year".[92] To account for this unpredictability architects or project managers would have to have kept a contingency fund.

6.1. Fluctuations in Material Costs

While the Price Edict gives maximum prices for different types of marble in the early 4th century AD—probably panels per ft^2, though some have argued for blocks per ft^3—it is by no means certain that there was ever a fixed price of stone in the Roman world.[93] Certainly a series of 2nd–century papyri from Heracleopolis in Egypt indicate great uncertainty over how much a consignment of porphyry panels would cost; and indeed they end up (as one might expect) being much more expensive than planned for.[94] This was certainly also the case in later periods, where the available data indicate that prices could fluctuate significantly but also vary considerably depending on the quality of the block of stone and its dimensions.

Marble prices from early 19th–century Rome indicate that the same stone types not only varied in cost year by year but also that different versions of the same stone were priced differently, depending on grain size and colouring.[95] This is echoed in a 1902 report on prices at Carrara, where it is stated that "so much depends upon color, quality, etc. of the various marbles produced at Carrara, that it is only possible to give the range of prices approximately".[96] 19th–century valuations of individuals quarries at Carrara support this with, for example, a quarry of first quality statuary marble estimated at 7500 *scudi*, while a quarry of veined marble was about half that; an "ordinary" marble quarry sometimes had a value as low as 40 to 80 *scudi*.[97] However, the 1902 report goes on to also stress that in terms of cost, "many things must necessarily be taken into account… location and proximity to the transport facilities, soundness, depth or thickness of the various veins, with consequent ability or inability to produce blocks of large size, amount of labor necessary to properly open the

[89] Knoop and Jones (1933a: 60).
[90] Ricci (1895: 132).
[91] Booth (1860: 73–75).
[92] Booth (1860: 74).
[93] On the units used in the Price Edict, see Corcoran and DeLaine (1994); Russell (2013: 33–36).
[94] *C.P.Herm.* 86, 94; Russell (2013: 25).
[95] Barbara Pettinau (1983).
[96] *The Carrara Marble Industry* (1902): 22045–22046.
[97] Maini (1851: 95).

quarry, are all important factors".[98] The impact of block size on price is particularly striking. An 1851 report shows that while the most expensive statuary marble cost 2.80 *lire* per cubic palm if between eight and 20 cubic palms in volume, the price rose to 11.20 *lire* per cubic palm for a block between 161 and 200 cubic palms in volume. There was no such thing as a simple price per cubic metre, therefore. And this fact is reflected in the British sources. For example, under the terms agreed for the rebuilding of St. Paul's cathedral, Thomas Gilbert and Thomas Wise (the agents responsible for supplying Portland stone in 1680) were paid higher sums for delivering large stones due to the added difficulty in their quarrying and transport.[99] The rates paid for the stone are shown in Table 9.

Sub–standard stone could also have impacted on the cost of projects. William Skyring, for instance, writing in the 1830s in Britain, complains that statuary marble "is now from 30 to 50 shillings per foot cube, at the wharf; taking all chances for its opening, which nineteen times out of twenty turns out bad, it is not uncommon for one mason to give another from ten to 15 shilling per foot super for good slab;… these marbles are so various in value that it is impossible to ascertain the equitable price without inspection."[100] For precisely this reason Booth encouraged all sculptors to select their own materials at the quarries: "if the marble worker chooses to order his marbles ready cut, he must take such as are sent to him; and, instead of making his own choice in the quarry, he is never sure of obtaining the finest, and often chances to receive the most defective, for the simple reason that the finest blocks are often selected before they are cut."[101] This was often done. Whenever possible, for example, Michelangelo preferred to select material himself at the quarries – he travelled to Carrara at least twenty times. If he could not go to the quarries himself, however, he was prepared to entrust the initial stages of work (quarrying and roughing–out) to other carvers, but these were always close associates, usually from his hometown of Settignano.[102] This kind of prospection would have cost: in 1442, William Hobbys was paid 6*d.* per day for eight days in which he rode to the quarries at Upton and Freme "to choose and examine good stones called Cropston" for the repairs at Gloucester Castle.[103] Similarly, in 1448–1449, John Denma was paid travelling expenses to Huddleston quarry so that he could arrange for a supply of stone.[104] But for many British carvers in the 19th century who relied on imports of marble, travelling to the quarries was unfeasible and would anyway have been expensive, and so a contingency fund was vital.

6.2. Supply Issues

Transportation costs could similarly fluctuate. Sometimes this was connected to the price charged by the haulier. In a letter dated to March 1517 from the sculptor Domenico Buoninsegni, who was in Rome, to Michelangelo at Carrara, the former notes that for three to five cartloads of marble the price should be no more than two to two and half gold *scudi* per cartload, for five to eight cartloads no more than three *scudi* per cartload, and from eight to twelve cartloads no more than four *scudi* per cartload.[105] These low prices, which started at

[98] *The Carrara Marble Industry* (1902): 22045–22046.
[99] Cambell (2013: 34). Figures approved at the meeting in Sept. 1680, London Metropolitan Archives, document: CLC/313/I/A/002/MS25622/1, f.44(r), and included in contract transcribed in full in WS XVI: 19.
[100] Skyring (1831: 82).
[101] Booth (1860: 57).
[102] Eric Scigliano (2005: 74, 77, 162).
[103] Knoop and Jones (1933a: 47).
[104] Knoop and Jones (1933a: 48).
[105] Giovanni Poggi *et al.* (1965: 261–262).

two *scudi* per cartload, are typical of prices at Carrara in this period.[106] Despite his awareness of regular price of Carrara marble, however, Buoninsegni himself had to pay above market rates in some instances: earlier, in 1505, for example, he paid 35 ducats for eight cartloads of marble, which was more than four *scudi* per cartload.

Bad weather and other unforeseen issues could also affect supplies of materials. The 16th–century Sens cathedral accounts provide some insight into the potential vagaries of river transport.[107] One shipper is recorded as having brought two barges from the quarries upstream as far as Montereau without problem but struggled at the confluence of the Seine and the Yonne and was forced to unload one of the vessels at Montereau. The stone that remained loaded was shipped the next month to Sens. A third of the cargo of the second barge, however, never arrived; this much stone had to be left behind in order for the ship to proceed upstream. Thomas Knight, who had a contract for the supply of Portland stone for the rebuilding of St Paul's,[108] regularly failed to provide stones needed, with others arriving damaged in transit and marked on delivery to the cathedral as unfit for use. Shipwrecks from both fluvial and maritime contexts show that consignments of stone were lost and never recovered.[109] A modern example shows that this kind of variability was not limited to pre–industrial contexts. Letters relating to the reconstruction of the Stoa of Attalos in the Athenian Agora in the 1950s show that quarrying and transport costs fluctuated wildly.[110] In a letter dated March 16 1954, Stuart Thompson records that while "the estimated cost of Piraeus stone was \$50.00 per m^3… the actual delivered cost [was] \$78.00 per m^3. This means that [the] final costs will be exceeded by approximately \$20,000." Bad weather during the winter in the mountains had caused the quarries to shut down for three and a half months, which had apparently created a "very great marble shortage resulting in much higher marble prices and greatly increased wages in the quarries." As a result, Thompson had to find two new suppliers to fulfill the demands of the project, with the result that the total was (with delivery costs) \$15,000 greater than the original estimated cost. However, Thompson also noted that the increase in stone price could be counteracted to some extent by the fact that the cost of work on–site was running ten per cent below estimated costs.

6.3. Labour Problems

Difficulties getting hold of both supplies and workers could also be caused by competing projects. This can be seen in 17th–century Rome during the large–scale projects carried out under Pope Alexander VII. In April 1661, Antonio del Grande (1625–1671), architect of the new wing of Palazzo Pamphili, justified delays in this construction by noting difficulties acquiring both materials and workers due to the drain on such resources by the construction of Piazza S. Pietro.[111] These accounts echo the complaints of Bernardino Parenti, the elder statesmen of the work crew, who was present on site in October 1659 and who stated that work was delayed because of "*mancanza di robba et hora per mancanza d'homini*" (shortage

[106] Caterina Rapetti (2002: 42 f.). Another note within Michelangelo's papers dated to July 9th 1517 penned by an unknown author, when Michelangelo was working in Carrara, also refers to prices starting from two *scudi* per cartload with a similar progression of prices for larger sized orders.
[107] Denis Cailleaux (1997).
[108]Campbell (2013: 31); WS XVI: 11–13.
[109] Russell (2013: 95–140); and on the impact of this on a building project, Russell and Leidwanger (forthcoming).
[110] The original letters are archived in the American School of Classical Studies in Athens. For this letter and the subsequent letters mentioned below, see Box 202/18, Folder I.
[111] Dorothy Habel (2013: 85–86) with reference original documents housed in the Archivio di Stato di Roma, Notai del Tribunale dell'Auditore Camerale, Ufficio 3 (H. Simoncellis).

of materials and now by a shortage of workmen).[112] The two-month delay in starting construction at the Palazzo Pamphili meant that the over 100 men who had originally been hired had moved on to work on Piazza S. Pietro.[113] This lack of workmen continued even during construction. Parenti had difficulties hiring workmen, especially *scarpellini* (stone–cutters), who were in high demand for travertine projects, particularly because of Piazza S. Pietro.[114] In order to combat just such shortages in workers or the presence of workers without materials or vice versa, that Fabbrica of St. Peter's introduced a syndicate system and required in their contracts that each mason provided materials and workmen at the same time.[115] This system created a monopoly for the syndicate that guaranteed the supply of materials and a steady workforce resulting in lower construction costs and quicker construction rates.[116] Smaller contractors, on the other hand, did not have this same guarantee of materials and workers.

Other delays could be caused by labour issues at the quarries. Insurrection at the Portland quarries in the 17th–century—a response to the awarding of exclusive rights to the Commission for Rebuilding St Paul's cathedral—caused significant delays in the shipment of stone.[117] Mismanagement at the quarries enflamed tensions. In March 1678, in fact, frustrated at the lack of communication from the quarries, the commissioners asked if someone living close to Portland could report back on what was happening.[118] They discovered the quarrymen were in open revolt and had smashed the piers used to load the stone in response to perceived poor work conditions and pay.[119] Comparable instances of lawlessness, including the theft of building stone and of illicit dealings in stone, is a regular theme in building records too. For example, at Leicester several cases of theft and sale of stone from town walls are recorded in the Municipal Records. In 1292, Richard of Thorpe, Canon of the Abbey, pleaded clemency for stone he purchased from Robert of the Dovecote, which he knew to have been stolen from the town wall.[120] In a report from York Minster compiled in 1344–1345, the master of works notes that "timbers, stone, lime, cement, and so forth have frequently been made away with; and that there has been much misappropriation of stone from the quarry, and that almost nothing is fit for the work brought in…" and that "the master of carpenters says that he does not know of any maladministration by the chamberlain except that he occasionally gives away stone, and he thinks that he receives money for the gift."[121] He continues with a litany of complaints: the masons have been paid too much and do not listen to the master mason; many are "not capable or fit", while some are disobedient; the workmen sometimes quarrel, "so that the work was often delayed"; and, to cap it all, "the carpenter is an old man and cannot work at high levels". Fines imposed on workmen for various offences are recorded in building accounts of Eton College, providing further

[112] Habel (2013: 97–99) with reference original documents housed in the Archivio di Stato di Roma, Notai del Tribunale dell'Auditore Camerale, Ufficio 3 (H. Simoncellis).
[113] Habel (2013: 97–99) with reference original documents housed in the Archivio di Stato di Roma, Notai del Tribunale dell'Auditore Camerale, Ufficio 3 (H. Simoncellis).
[114] Habel (2013: 97–99) with reference original documents housed in the Archivio di Stato di Roma, Notai del Tribunale dell'Auditore Camerale, Ufficio 3 (H. Simoncellis).
[115] The Fabbrica subcontracted as many as seven firms. See Habel (2013: 105) and Maria D'Amelio (2003: 702, n. 21).
[116] Habel (2013: 105) and McPhee (2008: 369–370, with references to the original documents), who cites the example of S. Carlo al Corso, whose deputies petitioned the Fabbrica in 1665 to allow their purchase of travertine from the vendor of their choice.
[117] Campbell (2013: 31). The petition is reprinted in WS XVI: 11.
[118] Campbell (2013: 33), quoting the Minute Book housed in the London Metropolitan Archives, no. CLC/313/I/A/002/MS25622/1, f.29(v.))
[119] Campbell (2013: 33).
[120] Knoop and Jones (1933a: 55).
[121] Salzman (1967: 54–55).

evidence that workers often fought among themselves, as well as interfering with each other's work.[122]

7. Implications for Energetics

What does the above discussion mean for studies using architectural energetics to examine Roman architecture? Construction does not take place in a bubble and beyond labour constants, materials quantities, and transport figures are a range of other factors that need to be considered when assessing the cost of building projects. Most of the additional costs outlined above relate specifically to the wages of the workers employed on any given project but others concern the supply of materials and on–site management of the workforce and other resources. We suggest some solutions for acknowledging these "hidden" costs in energetics.

7.1. Modified Wages

Lists of wages broken down by specialist from prior to the 20th century show that it was common for high–end stoneworkers to earn at least three times more than a standard labourer and often much more. A standard stoneworker might earn double this. Studies using the Price Edict have tended to just employ a skilled worker daily wage and a non–skilled worker daily wage, the former double the latter. This has probably had the effect of flattening the hierarchy of skilled workers. At the same time, later variation in wages, even between neighbouring quarries, shows that using one set of daily wage rates for the whole of the Roman Empire is misleading. Known local wage rates, where available, should be used instead and scaled accordingly using the ratio suggested above; a wide range of wages are known and do indeed vary substantially between region.[123] In 2nd–century Egypt, therefore, where a labourer might expect a daily wage of one *dr.*, a reasonable estimate for a skilled stoneworker might be two *dr.*, and that for a high–end marble–worker three *dr.* At Rome, we might expect corresponding wages of two, four and six *sestertii*, or perhaps slightly higher.

7.2. Profit

In addition to basic daily wages, the figures examined above show the cost of hiring workers added considerably to the total labour costs, and the same might have been true for the supply of materials. These extra funds—which we call profit—would have been consumed primarily by the various site managers and contractors who coordinated the workforce and supplied raw materials; some may also have gone to skilled workers providing their services as sub-contractors. For smaller organizations supplying large projects these profits were vital sources of revenue for growing their operations; for larger entrepreneurs, these funds were their main source of income. As Hodgson puts it, "builders' prices are broadly made up of two divisions, labor and material, to which may be added a third, namely profit."[124] The recorded profits in historical accounts range from *c.* six to 37 per cent. In the building manuals such profits are regularly referred to, with the recommendation that these should be calculated at ten to 20 per cent of the final costs of both materials and labour. Morisot suggests that 16 per cent is added to the base costs of materials and labour to account for these "benefices",[125] while the British price–books, notably those by Elsam and Skyring,

[122] Salzman (1967: 56).
[123] On wages, see Domingo (2013); Drexhage (1991).
[124] Hodgson (1904: 14).
[125] Morisot (1820: 34–36).

assume a figure of 20 per cent profit in their estimations of daily payable rates.[126] Rea gives figures that vary by project size: 15 per cent profit added to small projects (classed as projects or orders up to £5000) and ten per cent for large projects.[127]

A figure in this range, therefore, should be added to the final calculation of both labour and materials totals when translating these into monetary costs; it is an add–on cost, therefore, rather than an extension of either the labour or material costs. Only in cases where we know that the labour or the materials were provided "at cost"—for example, on municipally-funded projects using materials drawn from public land—should these additional totals be ignored.[128]

7.3. Incidental costs

Beyond profit, it is apparent that any building project had to deal with a range of others costs related to provisioning the workforce. For stoneworkers the key costs were tool supply and maintenance and accommodation or workshop space. In the case of the tools, we do not know whether Roman stoneworkers were expected to bring their own and pay for their upkeep or whether this cost fell on the project. Later, however, this cost was usually met by the project and when it was not this is clearly stated. Calculating how many tools would be needed on any given project is complicated by the fact that in most cases we do not know how many workers were employed on a project. What the figures above do show, however, is that whenever stoneworkers are employed, we should also add in metalworkers to the total workforce, at a typical ratio one metalworker for every four to eight stoneworkers, depending on the hardness of the stone. Equally, although an accurate estimate of how many tools would need to be sharpened daily cannot be produced, without knowing the total size of the workforce, for moderately hard stones like limestone and marble, it can be assumed that each stoneworker would need one tool repaired or sharpened per day. Finally, while it is difficult to quantify accurately the cost of accommodating or sheltering these workers, the potential expense of this work can be appreciated in the figures outlined above.

All this being said, this range of incidental costs was understood by the authors of the various 19th–century manuals. They are dealt with in most detail by Morisot, who gives a general cost of such expenses (*faux frais*) for basic masonry and then also for specific types of work. He calculates this by working out how much a team of workers would cost to employ over a particular period and then the cost of everything they would need to make their work possible in the same period. For general masonry, Morisot advises adding about six per cent of the cost of actually employing the workers to any final total to account for such costs.[129] This is close to the ten per cent that Rondelet adds to his daily rates for stoneworkers to cover such costs, making them more expensive than many other types of worker.[130] When marble is involved, however, Morisot notes that the cost of equipment and materials means that these totals rise considerably, to 17.5 per cent for the sawing of marble and 21 per cent for carving and polishing marble.[131] Comparable figures are given by Ricci, who suggests that such incidental expenses for marble–working should be estimated at eight to ten per cent the cost of the whole project with a further ten per cent taken up by the cost of supervision and security.[132]

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[126] Elsam (1826); Skyring (1831).
[127] Rea (1902: 3–4). Likewise, Hodgson (1904: 15–16) also recommends the standard addition of ten per cent to account for profit, but with the higher figure of 15 per cent for small jobs costing up to $2500.
[128] On this possibility for some municipal projects, see Russell (2013: 55).
[129] Morisot (1820: 26–33).
[130] Rondelet (1867: 78).
[131] Morisot (1824: 63–67).
[132] Ricci (1895: 132).

The impact of stone hardness on these totals is most carefully documented by Ponza (Table 10). Here we can see that he uses Morisot's figures of 17 per cent for sawyers and 20 per cent for marble–workers but also breaks down the incidental costs for regular stone carvers by the hardness of stone they were working in: his third–class carvers, therefore, were those working in soft stones (1800–2200 kg/m^3); his second–class carvers those working in medium stones (2200–2600 kg/m^3); and his third–class carvers those working in hard stones (2600–3000 kg/m^3), which would include marble and all harder stones. For carvers in the last of these categories he suggests adding a massive 31.5 per cent to their daily wage. These totals might seem excessive but the figures outlined above, especially for granite and granodiorite carving, demonstrate the impact stone hardness could have on tool maintenance especially. Furthermore, while Pegoretti does not talk specifically about incidental costs, he does give a breakdown of the cost of tools required for a team of ten carvers (*scalpellini*), which he quotes from Ponza.[133] Here he lists three categories of tools, their one–off cost and their annual cost, for maintenance and sharpening: 1) tools that every team need, including crowbars, rulers, set–squares, costing 334 *lire* initially and 36 *lire* per year; 2) carving tools for use on soft stones, costing 222 *lire* and 230 *lire* per year; 3) carving tools for use on medium stones, at 384 *lire* and 613 *lire* to maintain; and 4) carving tools for use on hard stones, costing 520 *lire* per year and 2471 *lire* annually. Tool costs for carvers using these harder stones, therefore, added up to nearly seven times the amount that carvers of softer stones had to spend. At the same time, tool costs are only part of the total calculation of incidental costs.

How should we account for these various incidental costs in architectural energetics? Several of the totals given by Ponza are clearly outliers. At the top end of the scale, his total of 31.5 per cent for carvers of hard stones, for instance, makes little sense compared to his marble–workers total of 20 per cent, especially if one considers that marble is defined as a hard stone in his categorization. This total makes much more sense if Ponza is thinking about granites or granodiorites. At the other end of the scale, Ponza's total for quarrying seems too low. Payments in building accounts point towards a distinction between the numbers of smiths needed at quarries and those on building sites, even ones requiring large quantities of stone.[134] As noted above, at Eton College a project with little or no quarrying had few payments to smiths, while those like Caernarvon, which involved large–scale quarrying, had a significant number.[135] Evidence from building accounts therefore suggests that it was quarrying much more than the dressing of stone that blunted tools and therefore demanded a higher ratio of smiths. Equally, while Ponza distinguishes between different types of stone when considering carving work, he does not propose such a division when listing quarrying. Considering these issues, the simplest solution would seem to be, as Morisot, Rondelet, and Ricci propose, adding a general total for "incidental costs" to the wages of all stoneworkers, modified by broad stone types. For projects on which soft stones are used, therefore, notably soft and medium–hard limestone and sandstone, Morisot's six per cent total would seem to be a reliable middle ground figure between Ponza and Rondelet. For projects on which marble is the standard material, a figure of 20 per cent, as given by Morisot and Ricci is probably more reflective of reality. Finally, for granite–working and for carving of even harder stones, this total could reasonably be pushed as high as 30 per cent. The only exception to this general rule should be quarrymen, who required considerably more investment in tools and, in particular, the sharpening and repairing of tools; for these, we would suggest that an additional 5 per cent should be added to each total.

[133] Pegoretti (1843: 237).
[134] Knoop and Jones (1933a: 63).
[135] Knoop and Jones (1933a: 63): At Caernavon, for example, in October 1304 there were five smiths supporting 32 hewers, 25 layers, and 34 quarriers.

7.4. Contingency funds and excess materials

On any given building project, material and transport costs could fluctuate dramatically. This was probably as true in Antiquity as it was in the Medieval and Early Modern periods. The availability of materials and workers was also unpredictable, with bad weather or other unforeseen incidents potentially jeopardising supply networks. Any of these factors could add significantly to the cost of a project and so budgeting for a contingency fund would always have been necessary. A figure of five per cent of the total predicted costs of materials, labour, and transport would seem a sensible estimate here, particularly if a total for profit has already been added to any calculations; no source, however, provides a recommended total for a contingency fund.[136]

When it comes to supplies, damaged or faulty materials presented a particular challenge. A contingency fund would allow for replacement materials to be purchased but would do little to off–set the time lost ordering in and waiting for these to arrive. If raw materials were brought from some distance, this delay could have had significant ramifications for the entire project. As a result, most building projects imported more materials than they needed, on the assumption that not all would be useable. This was a different sort of contingency, a material rather than a financial one. A sensible surplus ensured that new orders did not have to be continually placed with quarries, mitigating the risk of spiralling transport costs. Rejected materials but leftover surplus items, ordered in but never used, were not wasted. They became part of the 'unintentional stock' of architects, masons, contractors, and even the commissioners of building projects, and could be recycled, re–used, and sold on.[137] In Medieval England, permanent or semi–permanent works departments connected to long–term projects often engaged in trading of surplus stocks of materials. The Fabric Rolls at York Minster record receipts under the heading 'sale of stores', with sales from £3 3*s.* 5*d.* to £38 2*s.* 7½*d.* per year (between 1399 and 1458). With an average sale of £14 4*s.* 1*d.* per year, this equates to a total of £142 1*s.* 1½*d.* (or just over 7,000 days of skilled labour based on a daily wage of 6*d.*).[138] These sales include stone bought by the City of York (1433), Kirkham Priory (1444), the Keeper of the Fabric of St. Sampson's, York (1444), and the Keeper of Beverley Minster (1456).[139] At Eton College in 1448–1449, stores of Caen stone were sold to the wardens of St. Bride's in London for £4 5*s.* 6*d.*[140] Similarly, McPhee and D'Amelio have both noted that during the 17th century, the *cantieri* of Rome regularly brought marble, stone, and lime from the Fabbrica of Saint Peter's, and when these off–site projects were complete, they sold their leftover goods back.[141] While ordering in surplus materials as a contingency would have added to the initial cost of any building project, these were materials that could be sold on if not used; indeed even on damaged items, some costs could be recouped by recycling them or cutting them down and re–selling them.

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[136] This is especially evident in Hodgson (1904: 14), where he states: "such things as closeness or slackness of supervision, misunderstandings as to the quality of workmanship or materials, worrying by the architect, delay in furnishing details drawings, differences in locality and site, frost and bad weather, sudden and unexpected rises and falls in the market, etc., will all help alter the condition of profit or loss for the contractor, and the extent of which is almost impossible to measure".

[137] On "unintentional stock", Russell (2013: 232–235). For the recycling of such materials, see Barker (2019).

[138] This is from ten rolls. Knoop and Jones (1933a: 54). For details of the individual payments, see Raine (1859: 13, 25, 32, 49, 51, 55, 59, 62, 66, 70).

[139] Knoop and Jones (1933a: 54).

[140] Knoop and Jones (1933a: 54–55).

[141] McPhee (2008: 349); D'Amelio (2002).

8. Conclusions

Any assessment of the total cost of an ancient building project—as opposed to just the labour requirements or timescale—needs to take account of a range of expenses beyond just the labour totals, material requirements, and transport costs that form the backbone of most studies employing architectural energetics. Incidental expenses to cover tools and accommodation, for example, as well as the need to provide contractors and others with a profit margin and maintain some sort of contingency, could add considerable sums to the cost of building projects. In addition, we need to ensure that the wage structure applied to ancient projects reflects to some degree the hierarchy of workers' wages seen in all periods. While most studies of Roman architecture using architectural energetics have tended to distinguish between just two levels of worker—skilled and unskilled, the former earning double the daily wage of the latter—a more accurate hierarchy might include a third level, with "highly skilled" workers earning a daily wage three times that of an unskilled worker. On most building sites, of courses, such highly skilled workers would only have been used for most intricate carving and specialist tasks, such as figurative carving, decorative *opus sectile*, or the very finest drillwork; the bulk of the rest of the carving work, including even capital carving, could have been carried out by carvers in the second tier.

How, then, should these additional figures be applied? In Table 11 we propose a revised wage structure for different types of individuals involved in stoneworking. For all levels of workers totals of six, 20 or 30 per cent, depending on the stone type used, have been added cover incidental expenses, with slightly higher figures for quarrymen. To the total labour costs a figure of ten per cent should also be added to cover profits and an additional five per cent as a contingency. Beyond labour, transport costs should also have ten per cent added to them to account for profit as well as five per cent as a contingency. In terms of materials costs, ten per cent should be added for profit again, five per cent as a contingency, and additional materials accounted for to ensure a surplus: we would suggest that five per cent should be added to the total material costs for this aspect, assuming that ten per cent of surplus was originally ordered but that at least half the value of this or other excess materials could have been retrieved during resale.

The various totals listed above add significantly to the cost of any building project: between 21 and 50 per cent to the labour costs of stoneworkers, 15 per cent to transport costs, and 20 per cent to raw material costs. These are, of course, all estimates; all of the totals used in architectural energetics necessarily are estimates. What we have attempted to do here, however, is add up all of the various "hidden" costs revealed in building manuals and other sources, costs that were vital to the successful running of large–scale projects. The totals above are rounded, easily applicable figures that help to account for the difficulties und unpredictability of running building sites in the pre–modern era (and indeed many of the same contingencies are still taken on building sites today). We have concentrated in this paper on stoneworking, but other modes of construction were no different, even if the specific values for tool costs or other incidentals are likely to have varied considerably between specialist workers.

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Figures

Figure 1: “The Stonemason’s Yard” by Canaletto, *c*. 1725, National Gallery, London. The painting depicts a temporary stonemason’s yard situated in an open space known as the Campo San Vidal beside the Grand Canal in Venice, Italy.

Figure 2: Stonemason’s working at York Minsters Stoneyard’s Masons’ Lodge, located on the west side of York Minster, York, UK.

Tables

Table 1: Base daily wages for various types of stone workers given by Ponza (1841), Morisot (1820–1824), Rondelet (1867), and Pegoretti (1868–1869).

Table 2: Proposal of the categories of masons at Vale Royal Abbey and respectively wage rates. Based on Knoop and Jones (1934a: 20–23).

Table 3: Wage rates in the Marble Industry, in the Livorno (Leghorn) district of Italy, 1931. From ‘Wages and Hours of Labor’, in *Monthly Labor Review* 34, no. 5, 1932, 1128–1208. Published by the United States Government Printing Office, Washington: p. 1173, Table 5.

Table 4: Wage rates in the Marble Industry, in the Livorno (Leghorn) district of Italy, 1931. From ‘Wages and Hours of Labor’, in *Monthly Labor Review* 34, no. 5, 1932, 1128–1208. Published by the United States Government Printing Office, Washington: p. 1173, Table 5.

Table 5: Wage rates in the Marble Industry, in the Turin district of Italy, 1931. From ‘Wages and Hours of Labor’, in *Monthly Labor Review* 34, no. 5, 1932, 1128–1208. Published by the United States Government Printing Office, Washington: p. 1173, Table 5.

Table 6: Wage rates in the Marble Industry, in the Milan district of Italy, 1931. From ‘Wages and Hours of Labor’, in *Monthly Labor Review* 34, no. 5, 1932, 1128–1208. Published by the United States Government Printing Office, Washington: p. 1173.

Table 7: Various Wage Assessment for different classes of worker from Britain. From Knoop and Jones (1932: 25).

Table 8: Incomes of the mason–contractors who worked on St Paul’s in rank order. From Campbell (2009: 305, Table 3).

Table 9: Prices for the Portland stone used for the rebuilding of St. Paul’s cathedral, London (1 ton of Portland stone = 15 cubic foot or 0.42 cubic metres of stone). From Campbell (2013: 34).

Table 10: Wages for different stone carvers from Ponza (1841: 26-52).

Table 11: Summary of percentages that should to different cost categories to account for “hidden” costs.