The triumphal raising of the Vatican obelisk between April and September 1586, commissioned by Sisto V Peretti (1585–1590) to Domenico Fontana (1543–1607), starts a process of innovation and improvement in the building technology, heir of the Roman-imperial mechanics, which will reach a level of efficiency and functionality between the XVI and XVII Century, for a long time unsurpassed. What is the main contribution of the experimentation of Fontana to such technology, which persists at least up to the XIX Century? This experimentation is supported by the new impulse in the Roman building of the XV Century, as well as by the renewed interest for the mechanics, intended to create more functional and modern devices. In addition, it contributes to the development of an extraordinary organizational and technical system for building management, based upon the ingenious mechanism of the Reverenda Fabbrica of St. Peter’s and the entrepreneurial character of the masters of Lombardia, able to conjugate the Gothic constructive ability to a wise management of workers. From the first half of the XVI Century to the first half of the XIX Century, the Fabbrica is the real propeller of the Roman building economy. It is the institution assigned to control of the financial and technical administration of the Vatican building yard, similar to the «Opera del Duomo» in Florence or the «Fabbrica di St. Petronio» in Bologna (Basso 1987; Haines and Riccetti 1992, XI; Conforti 2001, 16). The Fabbrica of St. Peter’s can be considered a government institution, a technological and experimental workshop and a qualified school for skilled workers, at the same time. It is managed like a modern building enterprise, with a rigid hierarchical structure, and has at its disposal a large amounts of materials, tools and building machines, the so-called «munitioni», accumulated in centuries of building activity and stored in at least five stores inside the Basilica. These provisions have been accumulated from the period of Michelangelo’s supervision up to the construction of the portico, and also later. The purchase, use and loss of tools and materials are recorded in many documents of the Fabbrica of St. Peter’s. From the half of the XVI Century, the cardinal congregation supervising the Fabbrica develops a ingenious system for the hire and sale of these tools and materials, as well as for the «loan» of qualified manpower, the minor building yards. In this way, they can face the economic load required by the use of the big building machines, the purchase of expensive lumber and metal for construction, the provision of richer materials, like freestones and ropes (Rice 1997). This system is structured as follows: initially, the material to rent is carefully estimated and measured, then delivered to a representative of the applicant building yard, who becomes personally responsible for returning the material at the end of the works. Once returned, the material is re-estimated, to assess the wearing caused by use. In case of partial damage or complete uselessness of the material, a penalty is applied to the initial price of the hire, corresponding to a percentage
up to the complete value of the object, depending on the gravity of the situation. The difference between the initial and final estimation of the material represents the debt contracted by the minor building yard with the Congregation of St. Peter’s. Furthermore, all the materials remaining from the minor building yard, also those acquired from other suppliers, are purchased by the Fabbrica of St. Peter’s and added to its inventory. These exchanges sometimes enrich the Fabbrica considerably: between 1653 and 1654, the sale to the Sant’Agne se building yard of 164 pieces of travertine, coming from the demolition of the bell-tower of St. Peter’s (1647), yields to the Fabbrica around 4,000 scudi. A similar amount is obtained in July 1662 by the sale of the columns of same bell-tower, which are used for the churches of Piazza del Popolo. The meticulous estimation of the material also allows to understand the technical and constructive difficulties encountered by architects and workers during the works. The history of the objects concerns some of the most famous building yards of the Baroque Rome, like the Fabbrica of Santa Maria della Pace. For the frescoes of its dome, all the purlins, the boards of ilex, chestnut and elm wood, and the iron stirrups necessary to build the scaffoldings for the painters are taken on loan from the Fabbrica of St. Peter’s on 20th November 1650 and returned on 13th March 1665.1

In this system, the building technology, and particularly the building machines, have the most important role; in some cases they represent the only subject of the agreements between the Vatican Fabbrica and the minor building yards. What is the status of the building technology at the end of the XVI Century? The building machines, as shown by the treatises and the architectural iconography of this period, are quite similar to the ancient ones, like levers and chutes used by the Egyptians during the third millennium before Christ, or the building machines in use at the time of the Imperial Rome (Cupelloni 1996, 54).2 Nevertheless, a new interest for the applied mechanics appears in the XV Century, noticeable through the study of the X book of the De Architectura of Vitruvius and in the invention of spectacular and bizarre machines. A very famous example are the «alzacolonne» of Francesco di Giorgio (1439-1501), to whom Vasari attributes the revaluation of the machinatio, an integral part of Architecture (Fiore 1978). However, the technicians

Figure 1
The scenographic scaffold designed from Domenico Fontana for the raising of the Vatican Obelisk (Zabaglia 1743, fig. XLII)
Fabbrica of St. Peter’s. The scaffolds and building machines developed by Domenico Fontana for the removal, transportation and raising of the granite obelisks, either monolithic or «fracti», are conceived in a way that they can be applied also to the common practice. This is particularly true for the machines and tools used for the erection of the Vatican obelisk (Figure 1). Although initially acquired by the Fabbrica of St. Peter’s with a big economical effort, then will represent for the Fabbrica a very precious property for the following three centuries. Either used for the raising of other Sixtine obelisks (1587–1589) or rented to other building yards, they are a real source of gain. To raise the Vatican obelisk, having a weight of 400 tons, forty winches, five 15 meters long levers and 139,000 pounds of ropes are used (Figure 2). The iron tools, like pulleys, hammers, tackles, nails and rivets, partly come from the stores of the Basilica, partly are fused either in the papal foundry of the Fabbrica, or in the foundries of Ronciglione and Subiaco (Fontana C. 1694, 475–476). The papal foundry, located near Santa Marta in Vaticano, is used to make the «tragioni», big tackles in iron with six or four swivel joints, requested by Fontana. For their fusion, around 10,000 pounds of metal are used in addition to a large quantity of firewood (D’Onofrio 1992, 475–476). Most of the lumber used for scaffolds, «curli» and other machines comes from the woods of Nettuno, Terracina and Santa Severa, property of the Camera Apostolica (Fontana D. 1590, 6–7).

Due to the poor quantity of lumber available in the Roman country, the supplies must be optimized, the quantities must be exactly assessed, the process wastes must be strictly controlled, and the lumber reused where possible. To have an idea of the complexity of the scaffoldings, the one supporting the Vatican obelisk can be considered. It is composed of eight big masts («candele»), each one consisting of four wooden beams, joint together and tied up with ropes and metallic belts. There are four masts each side of the steeple. This structure is strengthened by a complex frame of braces, struts and trusses, and smaller beams placed either normally or parallel to the masts, in order to stabilize the structure and prevent the oscillations and the bending when the tackles are in use. The structure is also stabilized by eight ropes of big diameter, called «ventole», fixed to the top of the structure and anchored to stakes on the ground.

However, most of the building yards of Renaissance and Baroque have no need for such a complex technology, and use more traditional devices. This technology remains substantially unchanged up to the half of the XIX Century, when major modifications will be caused by the introduction of new materials, like cast-iron, or the use of electrical power. Until these changed are introduced, all the winches, «burbere», capstans, masts, gins and gin-poles, are made with wood and hempen ropes. Since very expensive, the use of metal is strictly limited to the manufacture of those parts subject to efforts and wearing, like tackles and pulleys.

The traditional character of the building technology of Renaissance and Baroque is evident from the inventory of the Fabbrica of St. Peter’s, as well as from the reports of other Roman building yards.
example of traditional building machine is the «antenna», a sort of wooden crane, either fixed to ground or mounted on a moving platform on four wheels. The «antenna» is connected to a winch, operated by twelve workers. Another person is responsible for winding the free end of the rope; other two control its tension. Also the «antenna» is stabilized by means of three or four «ventole». The stone blocks are lifted by means of a hoist composed of two tackles with four turns of rope. A picture of an «antenna» on wheels is shown in an anonymous drawing representing Palazzo Farnese under construction, at the time of the supervision of Antonio da Sangallo the younger (1483–1546) (Figure 3). The drawing is in contrast with the opinion of Filippo Maria Renazzi, editor in 1824 of the Castelli e Ponti of Nicola Zabaglia (1743), according to which Zabaglia was the first inventor of the «antenna» on moving base (Renazzi 1824, VI-VII). The «antenna» of Zabaglia is used in 1703 to position the 50 travertine statues of the St. Peter’s portico, work commissioned by Clemente XI Albani (1700–1721) and completed in only three months with only the help of young workers (Figure 4).

![Figure 3](image)
Anonimous, The building yard of palazzo Farnese at the half of XVI centuries (detail). On left side is visible the «antenna» (mast) used for lifting materials and stone blocks on the scaffold (Naples, BNN, Sez. mss e rari, ms. XII. D. 1. fol. 8)

![Figure 4](image)
The «antenna» (mast) designed by Zabaglia for installing the 50 statues of the St. Peter’s Portico in 1703 (Zabaglia 1743, fig.VII)

As shown in Table VII of Castelli e Ponti, it is a vertical mast composed of a number of minor beams, made of chestnut wood and joint together with metallic stirrups. It bears an horizontal beam (the «falcone») on the top, supporting the hoisting tackle (Marconi 1998, V 46–52). With this «falcone» the balustrade can be easily accessed and the statues can be exactly centered on their pedestal. The base of the «antenna» is installed on «curli», a sort of strong wooden cylinders with iron rings at both ends, which move the antenna’s base by rolling on the ground. Such device allows reducing the costs in a considerable manner, as it avoids the assembly and disassembly of the traditional scaffolds, otherwise required for the installation of each statue. Due to the considerable height of the statues (3 meters) and of the portico (17 meters), the «antenna» is stabilized by four «ventole»,...
two manufactured ad hoc for the work, two taken on loan from a «funaro» of the Fabbrica of St. Peter’s.⁶ The statues are raised by means of a big winch and a capstan made of ilex wood, mounted on the base of the antenna. Zabaglia analyses accurately each phase of the process, in all details, even the way to twist the ropes around a statue. For this purpose, he makes a small gypsum model of a statue, wrapped up with ropes, still preserved in the store of St. Peter’s.

However, in the common building yards the hoisting machines in use are frequently simpler. They can be «burbere» or capstans, small horizontal winches with tackles to raise wooden buckets containing various materials (Marconi 2001, 108–112). Also the gin («capra») is frequently used, either in the open or the closed version. It is composed of a wooden trestle supporting a hoist and a winch, and is used to lift big stones and statues, as well as to unload the big blocks of travertine and marble coming from Tivoli and Carrara, on ships sailing along the Aniene and the Tevere. The closed version of the gin consists of three masts linked together at one end with ropes, supporting a tackle (Figure 5). The rope of the tackle is connected to a winch fixed to the base of two of the three masts. On the contrary, the open version of the gin is stronger and of bigger dimensions. It consists of a trestle whose horizontal crossbar supports the tackles operated by winches (Figure 6).
Agone at the time of the supervision of Francesco Borromini from 1654 to 1658. For this work, commissioned by the Pamphilj family, the Fabbrica also provides 166 iron sturups, iron lifting pins, a «burbera» for the dome’s scaffolding, «culli», pulleys and tackles, and other minor tools.\footnote{7}

The primary role played by the Fabbrica of St. Peter’s in the Roman building is evident from the analysis of a number of significant building yards.

One is that started up for the restoration of the Pantheon’s portico, commissioned by Alessandro VII Chigi (1655–1667) from 1662 to 1667, to reinstall two columns on the eastern side replaced by a brick wall in the Middle Age (Marconi 1998, VI 63–87).\footnote{8} The Dominican Giuseppe Paglia (1613–1683), specialized in mechanics and hydraulics, is made responsible for this work. The problem of the replacement columns is solved in 1662 with the use of two columns of pink granite coming from San Luigi dei Francesi, probably traceable back to the thermal baths of Nerone. These columns are broken in two or three big parts, however they are used since similar to those on the front of the portico, high about 11.8 meters\footnote{9}. Their installation starts in August 1666 and is completed in the spring of the following year, thus in a really short time considering the entity and difficulty of the work. The work requires the removal of the brick wall, supporting the weight of part of the roof, concurrently with the re-assembly of the ashlars to reconstitute the columns. The organization of the building yard is evident from a synthesis of the expenses made by the foreman Giuseppe Bucimazza. He is the leader of a team of masons responsible for the leveling of the ground, the pavement of the square on the right side of the portico, and the execution of all the brick-works; while all the stone-works are assigned to three different teams of stonecutters, variously qualified. Sometimes they supply considerable amounts of travertine from Tivoli, the most precious. The manufacture of scaffolding and hoisting machines is mainly assigned to masons and stonecutters, rather than to carpenters. Considerable is the entity of the economical effort required for the works. The summary of the expenses of 26\textsuperscript{th} November 1666, only relevant to the works for the square, reports an expense of around 9300 scudi.\footnote{10} This summary also shows the difficulties encountered to assess the cost of the scaffolding and for the assembly of the columns. The costs involved are so onerous as to require the support of the Fabbrica of St. Peter’s to continue the works. Without such support, the foremen have to personally provide all the tools, machines and scaffolds, and are constrained to surcharge their fee. In particular, the provision of three ropes supporting up to 7000 kg and required for the stabilization of the scaffolds has a prohibitive cost.\footnote{11} One of these ropes is long around 290 meters and has a diameter of 19 cm; the resort to the Fabbrica of St. Peter’s is therefore inevitable.\footnote{12} The Fabbrica, also thanks to the intermediation of the Pope, supplies all the required materials and tools, and undertakes to pay for the manufacture of these ropes, provided that on completion of the works they become property of the «munizione generale di San Pietro e di Castello».

In November 1666, the responsible for the stores of the Reverenda Fabbrica («fattore») delivers to Paglia «le robbe per drizzare le colonne del Portico dell Rotonda», like tackles, pulleys, and various cuts of lumber.\footnote{13} The stonecutters, who physically carry out the installation of the columns, receive on loan many iron tools, i.e. 15 iron tackles, including the four big tackles used for the Vatican obelisk, picks, 66 sturups, lifting pins, etc. Most of these tools are returned to the Fabbrica in April 1667, for those damaged, the payment of their estimated value is requested.\footnote{14} The procedure to provide of the lumber for the scaffolds, two winches and a «tenda di canovaccio» — a waterproof canvas wide 190 mq used to protect the scaffolds— is similar. The installation of the scaffolds required to crib the coverage of the portico starts between December 1666 and January 1667. They are positioned partly below and partly outside the portico, as shown in the drawings of Nicola Zabaglia (Figure 7). The scaffolding consists of four primary masts, long 11 meters, and two rows of four secondary masts, supporting a frame of minor beams. The whole structure is strengthened with buttresses fixed to the ground and by an internal system of wooden stiffeners. Also a grid of ropes anchored to pickets stuck into the ground contributes to stabilize the structure. Once the scaffolding is completed, the portion of roof above the medieval wall can be removed and the wall demolished. The ashlars are then positioned in place, juxtaposed and joined together by means of iron dowels, sealed with lead. An adequate space for manoeuvring is made available.
inside the scaffolding, to enable the oscillations necessary to correctly pile the blocks. The capitals are positioned finally. They are lifted up and slid horizontally to reach the correct position above the column. Then the roof is rebuilt, and the surface of the columns, the lintel and the capitals finished off. Once the restoration is completed, the scaffolds are gradually dismantled so as to allow the structure to recover its original static equilibrium (Figure 8).

The supremacy and the primary role of the Fabbrica of St. Peter’s in the Roman Baroque building is also evident from the reports of the raising of two other monumental columns: one dedicated to the Virgin Mary in Piazzetta Santa Maria Maggiore (1613–1614), supervised by Carlo Maderno (1556–1629), and one dedicated to Antonino Pio in Campo Marzio (1703–1704), supervised by Francesco Fontana (1668–1708).

The raising of the column of Santa Maria Maggiore is one of the works promoted by Paolo V Borghese (1605–1621) to enhance the city of Rome. It has an urban function, that is to be a perspective focus for the square, like the obelisk of St. Giovanni in Laterano with which it is visually in contact, as well as a sacred function, that is the celebration of the Virgin Mary, through the statue installed on its capital. This column is a marble monolith of Corinthian order, coming from the Templo Pacis (or Basilica di Massenzio). The works are assigned to Carlo Maderno, not only because he is Architect of the Fabbrica of St. Peter’s, but also for his technical preparation achieved in the building yards of Domenico Fontana (his relative) and especially in that for the Vatican obelisk.16 The works begin in August 1613 and are completed after around a year, in June 1614.17 The organization of the building yard of Maderno is structurally similar to the Fontana’s enterprise, where teams of specialized workers and a rigorous planning of the jobs allow perfectly coordinating the all phases of the process.

The transportation and installation of the column is accomplished by the masons, with the support of sailors from the pontifical fleet for the operation of the ropes; also the realization of the wooden scaffolding is assigned to the masons, but with the contribute of carpenters and blacksmiths. The stonecutters are responsible for the stoneworks and also for providing the marble necessary to restore the
capital. The marble comes from the Templum Pacis as well.\textsuperscript{19} Also other artists take part to the works, like Guillaume Berthélot (1570–1648), who sculpts the statue of the Virgin Mary, and Annibale Corradini, who accomplishes the gilding of the statue. The lumber is provided directly by Maderno, who refers to the usual suppliers of the Fabbrica of St. Peter’s, to which he’ll resell all the lumber in excess on completion of the works, at the purchase price.\textsuperscript{19} Other materials are taken on loan from the Fabbrica, i.e. many big «curli» of elm wood, used to move the column from the Fori to Santa Maria Maggiore,\textsuperscript{20} 1160 planks of elm wood of various dimensions, 200 oaken boards, and also ropes, iron and leaden tools. On completion of the works, the ropes will be resold to the building yard of the Civitavecchia’s port, while part of the lumber will be used for the port of Fiumicino. It is possible that also the six-pulley tackles used for the Vatican obelisk were provided by the Fabbrica. The column is wrapped up with wooden planks and ropes, in order to protect its surface and be able to hook the hoisting tools. It is lifted, then placed horizontally on a wooden sledge, and towed towards Santa Maria Maggiore by means of winches, hoists and 60 horses. Here the column is positioned at the base of the scaffolding, which is very similar to that made for the Vatican obelisk. By means of winches, each operated by 16 men, and tackles, the column is lifted and simultaneously rotated to reach the vertical position, then lowered and positioned on the pedestal, to which it is fixed by means of iron dowels, sealed with lead. The capital is installed finally. It is inserted horizontally in the space between the top of the scaffold and the column, then lowered and positioned on the top of the column (Figure 9).

In 1703, another descendant of Domenico Fontana, Francesco Fontana, is commissioned to raise the column of Antonino Pio in Campo Marzio, in front of the Curia’s palace.\textsuperscript{21} This work can be considered one of the most sensational failures of the technology of the XVIII Century, as confirmed by analysis of the working process and the scaffolding used for the raising of this granite monolith from Assuan (Marconi 1999, 43–54). The analysis highlights the contrast typical of this period of transition between the outward trust in the new scientific research on one side and the continuous reference to the practice of the past on the other side, which is still the sole reliable instrument to control operational processes but is going to be forgotten and gradually unlearnt.

The reason for failure of the raising of Antonino Pio’s column can just be found in the concurrence of this fragility of mechanic science and the operational insecurity of designers and workers.

Although decisive in this case, the intervention of the Fabbrica of St. Peter’s is not sufficient to prevent the failure of the works. The unsucces is determined not only by the inaccuracy and lack of coordination of the manoeuvres accomplished, but especially by the erroneous position of the tackles on the top of the scaffold, which causes the supporting structure to yield in more points with consequent damage of the column (Figure 10). Neither the contribution of the Fabbrica of St. Peter’s, nor that of Francesco Fontana, can prevent
The baroque Roman building yard

ARCHIVES ABBREVIATIONS

AFSP = Archives of the Fabbrica of St. Peter’s
ASR = State Archives of Rome
BAV = Vatican Library
BNN = National Library of Naples

NOTES

1. AFSP, arm. 26. rip. E. vol. 393. 1r.
2. See also Usher 1954; Singer and Holmyard 1957; Drachmann 1963; Hodges 1970; Gille 1980; Martines 1999.
3. In Carlo Fontana’s treatise on Templo Vaticanum Alessandro Specchi shown the «Istrumenti serviti per il trasporto dell’obelisco vaticano» (tools for the Vatican obelisk’s raising).
4. The «curls» are a sort of strong wooden cylinders with iron rings at both ends, that move the building machines by rolling on the ground.
5. BNN, mss e rari, ms XI. D.1. fol. 8; Di Mauro 1987, 113–123. For information about Sangallo’s drawings of building machines, instruments and tools, see Scaglia 1994, 81–94.
6. AFSP, arm. 27. rip. C. voll. 397, 402, 396, 390.
7. One of the «antenna» will not be returned to the Fabbrica of St. Peter’s, since seriously damaged. Camillo Pamphilj will pay around 195 scudi to the
Fabbrica for this «antenna» and other scrapped tools (AFSP, arm. 7, rip. F. 466 and D’Amelio and Marconi 2000, pp. 406–418).

8. See also Fontana C. 1694, 473; Cerasoli 1909; Marder 1974, 1989, 1991; Pasquale 1996; Lucchini 1996.

9. BAV, ms Chigiani M. VIII. LX. 169r. See also Krautheimer 1985.

10. BAV, cod. Chig. PVII. 9.101, «Ristretto di tutto il denaro speso per il corrente giorno 26 novembre (1666) per il risarcimento delle due Colonie da rimettersi nel fianco destro del Portico».

11. To have an idea of the load capacity of this rope, consider that a rope of 5.5 cm of diameter has a load capacity up to 2000 kg.


15. AFSP, arm. 26. rip. E. 337. 83–84r.

16. Carlo was born in 1556 in Capolago, on the Lugano’s lake, from Paolo Maderno and Caterina Fontana, sister of Domenico. Carlo becomes Architect of the Fabbrica of St.Peter’s, together with Giovanni Fontana, in 1603, following the death of Giacomo della Porta (See Hibbard 1970).


18. ASR, Camerale I. Fabbriche. 1537. 266r.

19. AFSP, arm. 1. rip. A. vol. 2., 49.

20. ASR, Camerale I. Giustificazioni di Tesoreria. 39. f. 6. 4r.

21. Bianchini 1704; Cancellieri 1821; Crescimbeni 1705; Fontana C. 1708; Pellegrini 1881; Posterla 1705; Vignoli 1705; Vogel 1973.

22. From 1703 to 1704, Francesco Radice, foreman carpenter in the Fabbrica of St. Peter’s, skillful in scaffolding and hoisting machines, is paid for the works «all’antenna che ha servito per mettere in opera le 50 staute di truvertino sopra le Balastrate avanti la facciata di San Pietro, tanto che avanti la caduta di detta antenna, quanto dopo» In 1704, he also accomplishes the restoration of the three moving scaffolds in the Basilica of St. Peter (AFSP, arm. 27. rip. C. vol. 396. «Registro delle liste di operai e spedizioni 1695–1725».

REFERENCE LIST


The baroque Roman building yard


Zabaglia, N. 1743 Castelli e Ponti di mastro Niccola Zabaglia. Roma.