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SINAN’S ARŞİN: A SURVEY OF OTTOMAN ARCHITECTURAL METROLOGY

Koca Sinan, the chief architect of the Ottoman Empire for half a century (1538–88), is one of the most eminent representatives of Turkish culture. His genius in unifying art and technology has also been the subject of a vast number of studies by Turkish and other scholars. There still exist, however, several unknowns about Sinan and his architecture. The cubit, or ell, measure (arsın, argun, or şirə) that he was depicted holding in his hand as the emblem of chief architect, for instance, has never been scrutinized. When architectural historians today encounter a measurement given in numbers of arsin, owing to the lack of reliable information on Ottoman metrology, they must resort to converting it into the metric system simply by taking the latest recorded length of the mimar arşın (architect’s cubit). In reporting Sinan’s claim that the Selimiye Mosque has outstripped Hagia Sophia in the size of its dome, for instance, Gülürlü Necipoğlu appears to have done that when she puts the approximate metric equivalents in brackets:

And one of the things that people all over the world used to say was impossible was “a big dome like that of Hagia Sophia [which] has not been built during the Muslim era”, on account of this so-called architects of the infidels used to claim, “We have surpassed the Muslims.” The heart of this humble servant was troubled by their invalid presumption that “to support such a [big] dome is extremely difficult; if it were possible to match it they would have built one like it.” Working hard on the construction of this mosque, with the help of God “the King, the Conqueror,” and under the rule of Sultan Selim Han, I demonstrated my power by making the height of this dome 6 cubits [4.50 m] and its circumference 4 cubits [3.00 m] larger [than that of Hagia Sophia].

There are essentially five kinds of information one can gather on architectural metrology: first are the extant examples of measuring units or their materially recorded values; second, studies by modern scholars on the equivalence of current units; third, documentary references that compare measuring units with one another; fourth, references in contemporary texts to the dimensions of buildings that still stand today; and, finally, extracting units from the dimensions of buildings without the aid of contemporary texts. The first two are the most reliable, the third and fourth are suitable if used with caution; the fifth should be used with still greater caution. Results from this last source are so often unsatisfactory that here it will not be used at all. The fourth category will be used only when the given dimensions reflect a true survey of the building; in many cases the dimensions are given only in round numbers suggesting that they are merely the author’s guesswork. References of the third type will be used by providing the condition that one of the units is fairly securely known and by making allowances for its approximate nature.

Generally speaking, measuring units in a traditional society are among the most persistent elements of its unifying culture. Along with this persistence, however, is a flexibility that allows it to adapt to the gradual changes taking place in the society. Units may increase or decrease depending on the prevailing socioeconomic conditions, or new units produced reflecting differences in activities and interests. Edward Lane draws our attention to the former phenomenon in Egyptian metrology in the late nineteenth century:

Of the measures and weights used in Egypt, I am not able to give an exact account; for, after diligent research, I have not succeeded in finding any two specimens of the same denomination perfectly agreeing with each other, and generally the difference has been considerable: but in those cases which I have given the minimum and maximum, the former may be received as approximating very nearly to the just equivalent. The tradesmen in Egypt, from fear of Maktesib, mostly have measures and weights a little exceeding the true standards, though stamped by the government, which takes care to have such measures and weights employed in the purchases which it makes, and equal care, no doubt, to use those which are more true in selling.
Fear of the muhtesib, the official in charge of testing and certifying all kinds of measures in use in the marketplace, might not have been peculiar to the Egyptian tradesmen at the time. If their response to that fear represents the general attitude of the tradesmen during the Ottoman regime in Egypt and in the whole empire, it might have caused Ottoman measures to become gradually longer; and it would have been the main reason behind the chaotic diversity that Patrick Kelly observed in the early nineteenth century:

There is much uncertainty in the weights and measures of Turkey; and the standard lately transmitted from that country to London for the present work, rather increase the perplexity than diminish it. Even duplicates differ from each other, and their subdivisions are likewise out of due proportion. . . . The account of measures of Smyrna is chiefly taken from the dispatches and standards transmitted to Lord Castlereagh, in 1818 by Mr. Werry, the British Consul in that city. His statements, which seem very clear and correct, vary in many respects from the accounts hitherto published; but as authors on the subject differ very much among themselves, it may be concluded that Turkish metrology is not well understood or established. 5

These observations, mainly concerning measuring units in use in the markets, caution us to be extremely careful in our survey of Ottoman architectural measuring units starting with Sinan’s arşın.

Sinan claims that both the circumference and the height of the Selimiye Mosque’s dome were greater than those of Hagia Sophia’s dome. The actual dimensions of the two buildings, however, do not substantiate his claim. The distance from the apex of the dome to the ground in Hagia Sophia is 55.60 m; in the Selimiye Mosque it is 42.25 m. The interior circumference of any dome is virtually impossible to measure directly, but it can be obtained through calculation using the diameter. The diameters of these two particular buildings are difficult to compare because they are very irregular: the diameter of Hagia Sophia ranges from 30.90 m to 31.80 m; the diameter of the Selimiye Mosque ranges from 31.25 m to 31.75 m. 6

The measurements given by Sinan himself do not lend themselves to use for metrological purposes, but his claim was presumably so publicized that it should have prompted others to measure the two buildings. Edward Bernard reports in 1688 about an earlier survey of Hagia Sophia:

Moreover, Ibn Ma’ruf found 78 Hâshimi cubits, or 117 two-thirds [of the cubic], as the internal [height] of Hagia Sophia from the top of the dome to the pavement. Our Evagrius too prominently attributed 180 Greek feet to the height. The Arabs [i.e., Ibn Ma’ruf] also projected its round base, which is almost circular, onto the ground with a diameter of 44½ Hâshimi cubits and a circumference of 130. The true width of the whole temple is not less than 93½ cubits. The length, finally, of this most beautiful building is to be defined as 101 Hâshimi cubits. Nevertheless, it is possible to state on the basis of a module [of the cubic] of Ibn Ma’ruf in the Arabic manuscript in our library that the Hâshimi cubit is 28.9 English inches. 7

Ibn Ma’ruf cannot be anyone other than Taki al-Din Muhammad ibn Ma’ruf (1520–85) who was born either in Cairo or in Damascus but spent the later part of his life in Istanbul. 8 He was appointed chief astrologer to the court (müneccimbâs) in 1571–72 and was granted permission to build an observatory in Istanbul with the purpose of restoring the astronomical tables of Ulugh Beg. According to contemporary sources, construction started in 1576 and the observatory was equipped with all the necessary astronomical instruments. Before its completion, however, Murad III ordered it to be demolished in 1579, in response to criticism from the religious authorities.

Ibn Ma’ruf was an accomplished scientist who wrote several treatises on mathematics and astronomy, and invented some astronomical instruments himself. 9 The fact that he measured, or rather calculated, the circumference of the dome of Hagia Sophia — it was an unusual dimension to be considered in building practice — and that the measurements of the dome were mentioned first in his text suggest that his survey was related to Sinan’s claim. It was during the period when Ibn Ma’ruf was in office that Sinan was busy with the construction of the Selimiye Mosque (1569–74) and the restoration of Hagia Sophia. This must have given Ibn Ma’ruf the incentive and opportunity to measure and study Hagia Sophia closely.

It stands to reason that the “Hâshimi cubit” that Ibn Ma’ruf has used in his survey was the one generally employed by builders at the time. After the early period of Islam, the adjective Hâshimi, or interchangeably maliki (royal), was used as a generic term by contemporary Arab authors to distinguish the longer, or the longest, kind of measuring unit in use in a certain community. It was usually the one employed in surveying and building practice. Bernard, in his ambitious attempt to establish the Arabic metrology for all times, accepts the value given by Ibn Ma’ruf as
representing the length of the "great Hāshimī cubit." Apparently, Ibn Ma'ruf habitually used the term dhīrā' (cubit in Arabic) Hāshimī to differentiate the longer of the two types of measures used in Istanbul at the time: the builder's cubit.

Ibn Ma'ruf's figures given to the nearest full or half arşın appear to be fairly accurate measurements. As a mathematician-astronomer who was in charge of the construction of the observatory, he was certainly familiar with building surveying techniques. He would normally have chosen for his measurements the most convenient points with no obstructing features in between and clearly parallel/perpendicular to the walls. The height of the dome from the pavement, 55.60 m, can readily be determined. It yields the value of the arşın as 71.3 cm. As Bernard specifies that the base of the dome was projected onto the ground, we can assume that Ibn Ma'ruf simply measured at chest level one of the distances between the piers. Looking upwards at ground level, the distances on the east and west sides of the north-south axis of the dome are perceived as representing the diameter. He would have measured either one of these. Both measure around 32.70 m, which yields 73.5 cm for the arşın. Since the interior surface of the dome cannot possibly be measured directly, he must have calculated the circumference with the aid of the diameter. This measurement does not lend itself, therefore, to use for metrological purposes.10 The most convenient location to measure the full width, it seems, would be along the west wall. It measures 68.60 m, which produces a unit of 73.4 cm. We deduce from the words, "The true width of the whole temple is not less that 93/4 cubits," that this dimension corresponds closely to the nearest half cubit; thus, it should be taken as the most correct measurement. The length was apparently measured along either the south or north aisle, both of which measure around 74.20 m. It gives a unit of 73.5 cm. Although the values derived from the horizontal measurements agree with each other remarkably well, there is considerable discrepancy between these and the value derived from the height of the dome. It points to an error which perhaps resulted from the difficulty of measuring such an extraordinary height, and I therefore disregard it.

Ibn Ma'ruf also furnishes a module for the arşın in his manuscript. It is a rather common practice in manuscript to draw a module — usually one-third or one-fourth — of the cubit measure under consideration on the margin of a folio. According to Bernard's measurement in English inches, this particular module corresponds to an arşın of 73.4 cm.11 As it coincides perfectly with the values obtained from horizontal measurements, particularly with the most correct one, the length of Ibn Ma'ruf's arşın can be determined as 78.4 cm. The significance of Ibn Ma'ruf's account lies in the fact that, as chief astrologer, he was in a position to consult the royal standard measures, and, as a scientist — who was conscientious enough to initiate the establishment of the first Ottoman observatory to restore the existing astronomical tables — he most probably did so in order to use identical measures in checking Sinan's claim. Since the royal architectural standard measure was entrusted to Sinan's care, it seems likely that Ibn Ma'ruf's arşın was identical to Sinan's.

Ibn Ma'ruf was apparently not the only person who took it upon himself to check the validity of Sinan's claim. Evliya Çelebi (1611–79) tells us about a survey of the Selimiye Mosque:

When masters in the science of geometry gaze at its grand dome on walls, with no supporting pillars, they say "Great Sinan evidenced his great sagacity" biting their fingers in astonishment. Indeed, there has never been built under the blue sky such a spectacular dome resting on four walls. All the mathematicians/engineers marvel at its model of construction. They explain, "When measured with the širā', its circumference proves to be greater than the one of Hagia Sophia by a karş [span]." It really is a deep blue dome as of the heaven. However, it does not as high as the dome of Hagia Sophia. It [the Selimiye Mosque] is a lofty monument 58 širā' in height.12

Evliya's descriptions of buildings are full of exaggerated flattery and are therefore often misleading. When he cites dimensions, they are almost always guesswork meant to add an air of precision to his colorful exaggeration. Fortunately, his description of the Selimiye Mosque appears to be an exception. We understand from his account that some mathematicians/engineers, in an attempt to check Sinan's claim, measured the dome of the Selimiye. When Ibn Ma'ruf's survey is compared with theirs, Hagia Sophia proves to be loftier than Selimiye by 20 cubits (actually around 18). Evliya apparently felt that he did not have to praise it; it sufficed merely to report the fact. It can be assumed that this survey was made in the late sixteenth century when Sinan's claim would still have been a matter of public concern. The figure Evliya cites yields an arşın of 72.9 cm. It is close enough to Sinan's arşın
of 73.4 cm to be considered as an example of the builder's arsun of the time.

Indirect evidence from seventeenth-century Cairo roughly confirms the value we have established so far. The historian Muhammad al-Bakri (1596–1650), in his book, al-Kawākhīb al-sāʿira fī akhkhār Mīr wa'l-Qāhir, informs us: "The qasaba (perch) is 6 dhirāʾ (cubit) and two-thirds by the measure of trade, and around 5 dhirāʾ by the official measure." Al-Bakri covers in full detail the Ottoman period down to 1634. "The official measure," as al-Bakri calls it, was presumably the one imposed by Ottoman rule. John Greaves, in 1638, records that "the derah or cubit at Cairo" corresponds precisely to 1.824 English feet "taken from the iron standard at Guild-hall in London." It is equal to 55.6 cm. Antonio González draws the one-fourth "pic of Cairo" that was in use in 1665–66. The pic corresponds to 54 cm. Both reports cover the period al-Bakri was writing about, and what they were referring to, evidently, were the two specimens of "the measure of trade" in Cairo. The difference between the two recorded values was normal for ordinary measures. If we take the mean of these two, "the official measure" becomes 78 cm. We may thus assign, making allowances for the uncertainty involved, a length of 73 ± 1 cm for the dhirāʾ used in official transactions in Egypt in the second quarter of the seventeenth century, and this agrees satisfactorily with the value we determined for Sinan's arsun. Hence it appears that what al-Bakri is referring to was a duplicate of the Ottoman standard measure for surveying and building activities in Egypt.

In November 1520, after the Ottoman conquest of Egypt, an iron cubit (dhirāʾ min al-hadid) was brought to Cairo from Istanbul. Muhammad ibn Iyas tells us that according to a decree of Süleyman I, all the old measuring units used in the markets of Cairo were henceforth to be abolished, and only the Istanbul cubit that he had sent with his ambassador was now to be used by merchants and artisans. The sultan’s intention, it seems, was to bring standardization to the diverse measuring units in use in Egypt at the time by enforcing a single measure. We learn from Cafer Efendi that up to the early seventeenth century there were two types of measuring units in use in Istanbul: the common cubit (āmmeh arsun) employed by the merchants, and the builder’s cubit (bennebāʾ arsun) employed by the building trade. Which one was sent by the sultan for use by Egyptian merchants and artisans alike?

Ibn Iyas defines this new iron measure in terms of the carat (girāt, i.e., the twenty-fourth part or digit) of the Ḥāshimi cubit used in the Cairo markets. His account, however, only reflects the confusing state of the current Egyptian metrological system. On three separate occasions he gives three different evaluations of the cubit of Istanbul: 29 carats, 29.9 carats, and 30 carats. As the newly introduced standard itself could not have shown such a variation, Ibn Iyas apparently measured it against different specimens of the Ḥāshimi cubit of Cairo at the time. His account, therefore, does not aid us in determining the length of the cubit of Istanbul.

According to William Popper, in the Cairo Nilometer three different scales, composed of cubits and digits of varying number and size, were used successively in three periods: scale 1 in 1641–1522, scale 2 in 1522–1860, and scale 3 in 1860–1890. Scale 1, which was used by the Arabs before the Ottoman conquest, shows an average cubit length of 53.9 cm (28 digits) in the lower twelve gradations and 46.2 cm (24 digits) in the upper fourteen. The digits of both cubits, however, have a fixed mean, 1.925 cm. Scale 2, which was used in the Ottoman period, is again made up of two parts displaying two types of cubits, but both are divided into 24 digits. The lower nine gradations show an average cubit length of 54.1 cm and the upper eighteen are marked accurately at intervals of 36.07 cm. The fact that the cubit lengths in the lower parts of both scales are virtually the same points to the continuity of the traditional Arabic Nilometer cubit — which can in fact be traced back to the ancient Egyptians. The adoption of the cubit of 36.07 cm, practically two-thirds of the Nilometer cubit, meant a change from the old Arabic usage, in which all the cubits were multiples of the same digit. Popper connects scale 2 to the Ottoman conquest of Egypt and thinks that this new cubit was in fact approximately one-half the new Turkish cubit introduced into Egypt in 1520. According to pre-metric tradition, one-half the Ottoman builder’s cubit, which was called a kadem (foot), was the unit used in measuring depths of excavations or wells. We also learn from ‘Uthman al-Muhendi (d. 1553) that this traditional definition and use of the kadem was already in existence in the Ottoman Empire in the first half of the sixteenth century.

The Ottoman kadem appears as an exception in Islamic metrology which is solely based on the cubit measure. Originally, the "foot" was defined as two-thirds of the "cubit," i.e., the length of the forearm.
Although the original definition was preserved in Islamic metrology, a foot measure was not normally used on its own, and the cubit measures had become much longer than the natural cubit (approximately 44–45 cm). Since the upper gradations of scale 2 of the Cairo Nilometer are much shorter than even a natural cubit, they were most likely marked by the only foot measure in Islamic metrology: the Ottoman kadem. It appears that when Ottomans introduced the new Nilometer scale in 1522, they employed, alongside the traditional Nilometer cubit, their measure for measuring wells, as the Nilometer is essentially a well to measure the height of the Nile. Since the Ottoman kadem was defined as one-half the builder’s cubit, it must have been the cubit sent from Istanbul in 1520. The kadem of 36.07 corresponds by definition — and not approximately, as Popper suggests — to the builder’s cubit of 72.1 cm. It is interesting to note that scale 2 is thus composed of nine Egyptian and nine Ottoman cubits.

The cubit of 72.1 cm, the Ottoman builder’s cubit around 1520, appears as the original version of “the official measure” that al-Bakri refers to. Ibn Iyas’s account concerning the ceremonial introduction of the iron cubit of Istanbul allows us to consider it as the duplicate of the royal standard of Süleyman I, at least during the early period of his reign, issued as the builder’s arşın. The noticeable difference between this and the one we established for the late sixteenth century, namely Sinan’s arşın, suggests that various royal measures issued by Ottoman sultans were not calibrated against a fixed standard. This point gains credence when we study Baron de Tott’s (1733–98) detailed account of the construction of the castles that he was in charge of while he was in Istanbul:

While I was busy in forming Plans to take every Advantage which the Situation afforded, the Visir consulted the Astrologers, to know what day and hour were most proper for laying the first Stone. They had resolved the important Question and I was going to set out, to be present at this ceremony, when a Turk, followed by several Thooods, arrived, and announced that he came from the Grand Seignior [Mustafa III (r. 1757–74)]. The important Demencor of this Personage, and his silent Gravity, would not suffer him, hastily, to explain the nature of his Mission. The slowness with which he swallowed his cup of Coffee, that prelude to every Turkish Conversation, served, still more, to increase my Impatience.

At length, he drew from his bosom a small Bag of red Satin, with which he presented me, on the part of his Master; complimenting me, at the same time, on the Mark of Distinction it enclosed, and the Prerogatives attached to it. In the mean time, I opened the Bag, and took out a bundle of handkerchiefs, embroidered with Gold, in which were wrapped four Pieces of Ebony, joined by silver hinges and constituting the Measure or Standard of the Picel used in building. You may now, continued the Turk, dispose, at Pleasure, of all the Workmen in Constantinople; and the Pic of the Grand Seignior, intrusted to you, extends your Authority over them to the infliction of any Punishment.

Such high Privileges lost much of their value in my hands; but I was obliged to show what great Estimation I held them in my making the Bearer a Present.

I took the Standard, along with my other instruments, and set off for the place where the new Castles were to be erected. Here I found about forty Overseers of the Workmen and each provided with a double Pic. This mark of Authority making me recollect that which I had received, I resolved, while I waited for the astrological Hour, which was to bring the Ministers, to employ the time in examining the Measures of these Surveyors, in order to establish that Uniformity without which no exactness could be expected.

All these Gentlemen came round me with great Familiarity; and their Chief, who stiled and believed himself to be an Architect, and seemed to imagine I should listen to all he said, proposed to adjust all the Measures by his own. It will first, replied I, be necessary to examine yours: I immediately took from among my Instruments the little crimson Bag, and drew out the Standard: the Sight made the whole Company retreat ten Paces backward.

I took advantage of this first Surprize to establish my Authority, by an Act of Severity. which shewed my Power without being cruel. I commanded all their Measures, which, on examination, should not be found conformable to the Standard, to be destroyed; none of them, on trial, escaped; that of their Chief shared the common Fate, and I caused new ones to be made, on the Spot, divided all on the same Scale.

(u) Pic is the name of the Turkish El, but there are various kinds of this Measure. The French El [zoune] used to measure Cloth, is equal to a Pic and three quarters. The Indasai is another sort, used for the measurement of other Stuff, and the Pic employed in Building, which is the longest them all, is two Feet four Inches three Lines long. 22

Baron de Tott, a French artillery officer of Hungarian origin, helped institute the military reforms of Mustafa III; he reorganized the artillery corps, reopened the engineering school which had been closed
by the Janissaries in 1747, and founded a school of mathematics for the navy. As we learn from Baron de Tott’s account, Mustafa III also effectively appointed him chief architect with authority that extended within the boundaries of Istanbul. What is of particular significance is that the royal standard arsun was the symbol of this authority. The symbolism of the arsun was apparently the basis for the hierarchical organization of the builders as well: the overseers (presumably kalfa) of the workmen and the architects exercised the authority of their rank through the arsun they kept. We can infer from this that the Ottoman sultans made the appointment of the chief architects official by actually sending them a specially made builder’s cubit, presumably bearing the royal stamp, and that it served as the standard arsun of the time.

This, of course, poses a metrological problem: how were those standard measures made? As far as I know, before the end of the eighteenth century, there is no material or documentary evidence for, or reference to, the existence of a fixed standard measure which would have allowed the making of exact duplicates when the need arose. It may be that some of the sultans issued their own standards to the chief architects; it was probably made by a craftsman in the court who duplicated the previous standard or his own measure, if the order did not specify a change in the length.

Baron de Tott’s measurement of the royal measure that Mustafa III issued to serve as the standard builder’s cubit is equal to 76.4 cm. Including this, we have so far established three royal standard measures for the Ottomans: 72.1 cm around 1520, 73.4 cm in the fourth quarter of the sixteenth century, and 76.4 cm in the third quarter of the eighteenth century. During this period — for that matter, during the whole Ottoman era — there was no record of a new measure being introduced apart from several attempts at standardizing the current ones. Those three were the royal standards of nominally the same measure, but issued during the reigns of different sultans. A discrepancy of such magnitude, 43 mm, would not have occurred had there been a fixed gauge at the Ottoman court. Although our scanty information does not allow an accurate evaluation, the differences between them are ample enough to indicate that they tended to become longer. According to this assessment, what we call Sinan’s arsun might not necessarily be the only one he used throughout his long career, during which he served three sultans. The arsun of 72.1 cm seems to be the one used before he became chief architect.

It has to be emphasized that this interpretation is based only on standard measures. When specimens, which were inherently inaccurate, were made from standards that changed continually, the result would naturally have been chaos. That was what Baron de Tott apparently observed so often when he examined the measures of forty overseers.

“Due to the increasing variations of length for the builder’s cubit,” reports Salih Zeki, “Selim III [r. 1789–1807] ordered an architect’s cubit [mi’mar arsun] to be made from ebony and to be kept in the library of the Royal Military Engineering School for purposes of standardization and calibration.” Selim III, who undertook a vigorous program of Westernizing reforms, influenced by his father Mustafa III, had apparently realized that the only way for regularizing the measuring units was to issue a fixed standard accessible to the public. This gauge was made and placed at the aforesaid place in 1794–95. We learn from Guillaume-Antoine Olivier that the architect’s cubit of Mustafa III had served as the standard until this date. The arsun of Selim III, which was preserved in the same place up to 1934 (when all the traditional measures were finally replaced by the meter), served its purpose too effectively: it is regarded today as representing the architect’s cubit throughout the Ottoman period.

The mi’mar arsun of Selim III became the final and definitive version of the measures which were interchangeable called the building cubit, builder’s cubit, and, after the late seventeenth century, the architect’s cubit. When the metric system was adopted for the first time in 1869, its metric equivalent was determined as 75.8 cm. From 1794–95 onwards, this standard was constantly referred to by all the authors to determine the value of the architect’s cubit. We therefore cannot have a clear picture of the real state of affairs. On the basis of the information gathered from the extant specimens, deviations from the standard were generally negligible during the late period.

One face of the arsun of Selim III was divided into 24 digits (parmak) and each digit was subdivided into 10 lines (kat); the other face was divided into 20 digits, each digit was subdivided into 5 lines. It is believed that the decimal divisions of the second scale were a result of the European influence. According to documentary evidence, however, the Ottomans were familiar with decimal fractions long before the Europeans. Câfer Efendi in Risâle-i mi’âriye (1614) said, “Arithmeticians lay down the rule that the ’amme girâ’î is such
that a proper gir'ah is 100 barmak (digit), and each barmak is 10 ıplık (thread), and each ıplık is 100 ğar-i ısbislak (spider web). Nasuh Mattraki in 'Umdat al-hisâb (Pillars of arithmetic, 1517) tells us that, apart from the hexadecimal scale, a cubit is divided into 100 digits, a digit into 100 threads, and a thread into 100 spider webs. Mattraki's definition is also found in Muhyi al-Din Mehmed ibn Haccı Atmaca's book, Ma'amla al-Kav'id (Collection of rules, 1493) and in the Turkish translation (ca. 1500) of Miftâh-i kunûz-i arbâ-i kalâm misbah-i runûz-i ışkub-i rakam (The key of the treasures of the experts in writing, the lamp of the hallmarks of the masters in numerals) written in Persia around 1475. In a handbook on arithmetic written probably by an anonymous Greek scribe in Ottoman service who lived in Salonica in the fourth quarter of the fifteenth century, the operations performed by decimal fractions were identified as "the Turkish procedure." All these indicate that decimal fractions, which were devised by Ghiyath al-Din Jamshid al-Kashì in Miftâh al-hisâb (The key to arithmetic, 1427), had become popular among Ottoman Turks presumably after 1471, when his associate Ali Kuşçu settled in Istanbul and was appointed professor of mathematics. It has to be noted that Miftâh al-hisâb, judging by the number of copies of it in Istanbul, enjoyed great popularity there. The decimal scale of the arsun of Selim III, therefore, reflects only the long Ottoman tradition of decimal fractions, which were not recognized in Europe until the end of the sixteenth century.51

In Rızaâ-i mi'marîye, Cafer gives a detailed account of the Ottoman metrology of the time. The information he provides is of particular significance in establishing the Ottoman builder's cubit in the early period:

There are two types of arsun (cubit, ell). One type is the bennâ' arsun (builder's cubit). The second is the 'amlle arsun (common cubit), that is the gir'ah (cubit, ell) of the common people, as distinct from [that of] the architect. The bennâ' gir'ah's (builder's cubit) is twenty-four boğun [loopt, inel]. And each boğun is two and a half barmak (finger, digit). But architects do not employ boğun. They use [only] the barmak. It is a sort of metaphor. ... The total comes to sixty barmak. And the reason this gir'ah is of two types is that the 'amlle gir'ah's (common cubit) derives from commercial calculations. And this 'amlle gir'ah's is one hundred barmak. ... And they divided this gir'ah of a hundred barmak into thirty-two parts. And they called each of these parts a gir'ah. ... And [concerning] those thirty-two gir'ah, just as previously each of the four akçe (small silver coin) which were coined from the dirham (silver coin) was equal to thirty-two mankar (copper coin). But now, because the akçe is reckoned in a different manner, the science of arithmetic and the calculation of the gir'ah are absolute and void and completely in disarray. For many thousands of years, until the years ... [1585–87], that [earlier] reckoning of the gir'ah was valid. But from that date until the beginning of this year [1614], ... [that is] for exactly twenty-seven years, it has been abandoned. And now the 'amlle gir'ah's used by the common people is not that complete gir'ah. It is half the complete gir'ah, that is, sixteen gir'ah. And the complete gir'ah is still the gir'ah called the beş arsun (cloth cubit) among the common people. It is exactly thirty-two gir'ah. And the bennâ' gir'ah's is fixed in accordance with the canon law because those matters of canon law which require surveying [masâba] [in which the bennâ' gir'ah's is used] include the science of the division of estates ['ilm-e ferdâst]. To survey means to measure a place in cubits or simply to know its size. And matters relating to the science of the division of estates are for the most part governed either by sixths or twelfths or twenty-fourths. ... But the name 'amlle gir'ah's has become very corrupt. Some people make it short, some make it long. However, the truth is that in terms of the boğun of the bennâ' gir'ah's, forty boğun are exactly one ['amlle],gir'ah's, and twenty boğun are half a gir'ah.

... Now in order to measure various places in Rum-illi [European provinces] and the Islands, a knotted dönâm [the agrarian area measure] cord of the mentioned intermediate type is issued by the imperial treasury. And in accordance with an issued imperial decree it is noted that "that cord is, in bennâ' gir'ah's, forty-five gir'ah [long]. If people doubt and do not trust it, let them measure it with a ders arsun [tailor's cubit]. If that cord comes to fifty-five gir'ah with the ders arsun, let them trust its accuracy." In point of fact, forty-five gir'ah with the architect's gir'ah and fifty-five gir'ah with the ders arsun are [only] approximately equal.52

We learn from Cafer's explanation that the confusion created by Murad III's devaluation of Ottoman coinage in 1585–87 had affected the common cubits then used in trade. This and other economic crises — particularly the one around 1640 — might have had their impact on the canonical builder's cubit as well, since it too proved to become longer, though, it is difficult to understand how. Cafer informs us that for a very long time the defining ratio between the canonical builder's cubit and half the common cubit was 6:5. According to the royal decree issued sometime before 1614, however, this ratio had become 11:9, probably during the period of confusion following the
first devaluation. It appears that, in an effort to introduce some sort of standardization, the state was acknowledging the already changed ratio between the average lengths of these two measures and redefining it officially. Cafer himself seems to be disturbed by the fact that the latter deviates from the ratio which had lasted "for many thousands of years." This appears as an important development which marks the beginning of a new phase in Ottoman metrology. The values of these two measures recorded in later centuries never again yield the 6:5 ratio. For instance, in the imperial decree of 26 September 1869, the official length of the architectural cubit (75.8 cm) and of the common cubit (68.0 cm) yields a 1.115:1 ratio.34

Judging from Cafer's testimony, the inherent 6:5 ratio between the two Ottoman measures was never disturbed until about the end of the sixteenth century. We can thus estimate the average length of the common cubit in the first and the last quarters of the sixteenth century as 60.1 cm and 61.2 cm. In 1638, Greaves reported that in Istanbul the Turkish pike (pir, i.e., cubit) corresponds exactly to 2.2 English feet, that is, 67 cm.35 Between the economic crisis of 1585 and that of 1640, it seems, the length of the common cubit had increased considerably. Apparently, what Cafer was describing in 1614 was the confusion that process had created. Probably as a reaction to this, following the 1640 crisis a revolutionary plan for the standardization of all weights and measures was put into effect.36 The closeness of the length recorded by Greaves to the legal definition in 1869 suggests that the standard common cubit was fixed after 1640 somewhere between 67 and 68 cm and retained this value later without much change.

The inherent ratio between the two Ottoman cubits which was constant "for many thousands of years," as Cafer put it, allows us to establish the Ottoman canonical builder's cubit in the early period. Two separate sources from the beginning of the sixteenth century furnish quite accurate data concerning the Ottoman common cubit.37 In the summary tables of Tariffa de pess e mesure (1503), Di Pasi gives the correlation between the braccio (arm, the Italian unit of measurement) of wool of Venice and the picho of Constantinople and Bursa as 1:1.13. He repeats the same correlation for other major cities that were conquered by the Ottomans before the sixteenth century: Scutari (of Albania), Valona, Corfu, Arta, Lepanto (Naupaktos), Negroponte (Euboea), Chios, and Salonika. He mentions in the text that the correlation varied between 1:1.12–1:1.13 or 1:1.13–1:1.14. If we accept 1:1.13 as the average, the length of the braccio of wool of Venice that Di Pasi used, 67.0 cm, yields 59.3 cm for the length of the Ottoman picho. He also gives the correlation between the braccio of silk of Venice and some of these cities as 1:1.06–1:1.07. For the value of 63.1 cm, the Ottoman picho becomes 59.5–59.0 cm.38 The anonymous author of the Tariffa generale (the beginning of the sixteenth century) gives the correlation between the palmo (palm) of Genoa and the picho of Constantinople, Bursa, Lepanto, Arta, Corfu, Valona, and Scutari as 1:0.41–0.42. The average value of the Genoese palm at the time was 24.7 cm. The correlation thus gives 60.2–58.8 cm for the length of the Ottoman picho. He provides also the inverse correlation, 1:2.4, which produces an average length of the picho, 59.8 cm.39 As two independent evaluations from the same period coincide, we can safely accept 59.3 cm as the average length of the Ottoman common cubit at the beginning of the sixteenth century. In accordance with the inherent 6:5 ratio, the canonical builder's cubit at the time corresponds to 71.2 cm. This average value, which is slightly shorter than the royal standard in 1520, fits nicely into the general trend of Ottoman architectural metrology.

What we have observed concerning metrology so far covers the period of the culmination of Ottoman imperial power in Istanbul with all its metropolitan complexities and the period of decline with its intermittent economic crises. Before the sixteenth century, particularly before 1453, the Ottoman institutions, like the state itself, were rather modest and not very diversified. During this formative period, society was small enough to be ruled smoothly by a system of traditions — whether Turkish, Islamic, or local — rather than royal decrees. The stability that the system rendered should have had its effects on the cultural institutions, including metrology. It seems reasonable to assume that the measuring units in the early Ottoman period had retained their original lengths up to the sixteenth century. In other words, it is likely that the canonical builder's cubit in Bursa, while it was the capital, was around 71.2 cm.

When we compare the cubit of 59.3 cm with the one of 67 cm that Greaves recorded in 1638, we understand that Cafer was misinformed in claiming that after 1587 the 'amme ẓirā' became half the ẓirā' which had been in use "for many thousands of years." As he himself was not in Istanbul before the change, he was
possibly repeating the cloth merchants' claim that their measure, the bez arsun, was the true one and had a very long history. At any rate, we can deduce from the claim that, alongside the common cubit, the bez arsun of the double common cubit was in use in the early times. Its length corresponds on average to 118.6 cm and thus recalls the French oun of 118.8 cm which, in all likelihood, came from the Roman unna of four feet, on average 118.4 cm (4 x 29.6 cm). That brings up the question of what the roots of Ottoman linear metrology were.

Concerning the Ottoman's general attitude towards metrology, Inalcik writes:

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\text{Ottoman conservatism regarding measures is in complete conformity with the gradual Ottoman process of integration of an area into the imperial administration. It was a policy of the Ottomans to keep the pre-conquest laws and customs to which the indigenous population was long accustomed. Their abolition, it was thought, would entail difficulties and discontent. As will be seen, change often was simply the replacement of the pre-conquest terminology with the Ottoman one. This process usually took quite a long period of time, and in some cases it was never completed.}^{41}
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It was perhaps the reason why, while the term arsun or girân was persistently used by Ottoman authors and in official communications, the Greek term pic was invariably used by European authors — in particular Greaves and Baron de Tott who made a point of using the local terminology. This duality may imply that, contrary to the bureaucratic approach, pic was another interchangeably used term among the common people. If that was the case, it suggests the possibility of a Byzantine origin for Ottoman measuring units. Given the Byzantine influence on Ottoman civilization in the formative period, it is a feasible proposition.

Cafer's phrase, "for many thousands of years," gives the impression that the inherent relation between the Ottoman measuring units had a long history, going well beyond the formative period when the Ottomans had been familiar with Byzantine civilization. Given the remarkable similarity between the length of the bez arsun and the recognized average value of the Roman unna, one expects to find the continuation of the Roman measures in Byzantine metrology. The values of the Byzantine measuring units of trade recorded in fourteenth- and fifteenth-century Italian manuals, however, do not substantiate this. According to the information gathered from treaties like the Pratica, the Tarifa zoè notica, the Pratica della mercaturo, and the Libro che tracta, in Constantinople the common pic (or the pic of St. Nicholas) had a value of around 56 cm which was two-thirds of the Crimean pic (or the pic of Pera), which was around 84 cm.\textsuperscript{42} Ottoman measuring units were evidently not related to the Byzantine commercial measures that were in use during the formative period. Di Pas\textsuperscript{46} makes this point abundantly clear by repeatedly referring to the measuring units of the cities newly conquered by the Ottomans as the Turkish picho and specifically adding the note: "At present they measure by the Turkish picho." If the hypothesis is true, then the link was not commercial measures but possibly measurements of distance or of land which were not likely to be recorded in contemporary sources.

Jean B. D'Anville reports in 1766 that the Turkish mile is equal to 758 French toises.\textsuperscript{44} His measurement corresponds to 1,477 m. In 1850 Alexander gives the length of the Turkish mile as 1,479 m and adds that it corresponds to the Roman mile.\textsuperscript{45} Indeed, both measurements correspond very closely to the Roman mile (1,000 passus [double paces]) of 1,480 m, which is composed of 5,000 feet of 29.6 cm on average. Given the resistance of measurements of distance to change, one can assume that the Roman mile was adopted first by the Byzantines and then by the Ottomans until the nineteenth century.

The traditional Turkish agrarian unit of measure, the dönüm, was loosely but invariably defined as a square the side of which was equivalent to 40 ordinary paces (yürümek adınsı). In the 1858 avaz kânun-nâmesi (the law code for the arable land in 1858), a more accurate definition is provided: 1600 m\textsuperscript{2} m\textsuperscript{2} arsun\textsuperscript{46}, that is, 918.67 m\textsuperscript{2}. In the nineteenth century, apart from this legal Ottoman dönüm, another type was recorded: 1,270 m\textsuperscript{2} for soil of inferior quality.\textsuperscript{37} The side of this square corresponds to approximately 35.6 m. The latter dönüm seems to suggest the existence of Roman agrarian measures in Ottoman times. The common Roman agrarian unit for area was a square actus, or 12 x 12 pertica (perch) of 10 Roman feet. On average, the linear actus corresponds to 35.52 m. Actus in Latin and dönüm in Turkish have the same definition: the distance that oxen pulling a plough would be driven before turning.\textsuperscript{48} The actus also corresponds to 10 pertica of 12 Roman feet, or 10 feet of 35.3 cm. A nineteenth-century dönüm is rather flimsy evidence to bridge a gap of nearly two thousand years, but it is tempting to note that Hero of Alexandria (1st century a.d.), a native of Egypt who wrote in Greek,
gave the following definitions: “The royal or Philheteric foot is 4 palms, 16 fingers; the Italian foot is 13½ fingers. ... The stoic ell is 8 palms, 32 fingers. ... The akna (perch) is 6% [common] ells, 10 Philheteric feet, 12 Italian feet.” They give the impression that the 6:5 ratio between the royal foot — which corresponds to two-thirds of the Ptolemaic version of the royal Egyptian cubit — and the Roman foot was defined when the latter was introduced into the prevailing metrological system in Egypt. It may be that the Romans, after setting up the province of Asia, rationalized the most important linear measures of the Hellenistic East in order to facilitate conversions and to create uniformity for fiscal transactions. The alternative word for the royal foot may also imply that it was widely used at the time in western Anatolia (Philetarios was the founder of the Hellenistic kingdom of Pergamon). According to Hero’s definition, the stoic ell corresponds to 71 cm: a distant reminder of the early Ottoman canonical builder’s cubit.

Hero’s works on applied geometry had served as the model for both the works of Roman land surveyors and for Arab works on the science of measurement, mīṣāḥa. It is conceivable that the metrological system he described — based on the 6:5 ratio between the Hellenistic and Roman measuring units — had spread over the east Mediterranean countries through Roman, Byzantine, and Muslim land surveyors, and in the course of time was established as the structure for the common agrarian measuring units of those lands. Particularly among western Anatolian farmers, it may seem, it had a better chance owing to the Hellenistic measures that they traditionally shared with it. Preserved by the strong resistance of agrarian measures to change, the Roman ʿulna and the stoic ell might have survived all the sociopolitical upheavals and reached the Ottomans as material folkloric elements of Anatolian culture. Thanks to the strict adherence of medieval peoples to their traditions, it seems, the Ottoman bez arsuni and bennəʿ arsuni had retained their original values up to the beginning of the sixteenth century and their inherent relation until about the end of the century.

It has to be emphasized that, apart from a Turkish mile and a dönüm recorded in the eighteenth-nineteenth centuries and the conservative tendency of distance and agrarian measures, this hypothesis cannot so far be substantiated by sufficient evidence. It would be safe to conclude in this study that the Ottoman architectural cubit, which had been subjected to considerable alterations between the sixteenth and nineteenth centuries, was probably stable during the fourteenth and fifteenth centuries, and it may plausibly be traced back to Hellenistic-Roman-Byzantine metrology.

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NOTES

1. A portrait of Sinan holding an arsuni is reproduced on the jacket of Metin Sönçü and Sufiş Şahin, Mimar Sinan ve Tekerli-ül Bûnûn (Istanbul, 1989).


3. There are quite a number of studies on Islamic metrology. In them the general tendency is to establish sweeping values for certain standards of measure referred to in contemporary texts, usually based on imprecise information about measuring units and inaccurate definitions of terminology, and arrived at by computations that assume they were true at all times. The fact that the terms were often used interchangeably and that the specimens of the units, as is so often mentioned in the texts themselves, varied a great deal was usually ignored. Hinze’s handbook on Islamic metrology (Walter Hinze, *Islamische Massen und Gewichte angerechnet ins metrische System* [Leiden, 1955]), which is the one generally used by scholars of other disciplines, suffers from similar misleading evaluations.


5. Patrick Kelly, *The Universal Comptist and Commercial Instror* (London, 1821; 1st ed. 1811), pp. 73, 315. It is not difficult to understand why Kelly found Turkish metrology perplexing. In his time, quite a number of types of measuring units existed, and each one showed considerable variation: ruđar (60–65 cm); parsa arsuni (66–69 cm); Huleb (70–71 cm); mīrār arsuni (74–77 cm); Buğdadi (82–85 cm). These sketchy statistics are gathered from the measuring units found in various museums and the records in the following eighteenth- and nineteenth-century sources: Alexis J.P. Panckon, *Mémoire sur les mesures, poids et monnaies des anciens peuples G. des modernes* (Paris, 1780); Jürgen Elert Kruse, *Allgemeiner und besonders handelsmäßiger Centurien* (Hamburg, 1784); Kelly, *Universal Comptist* (cited above); Johann P. Heuer, *Ueber bürgerliche Maas und Gewichte* (Elberfeld, 1830); Horace Dauvers, *Dictionnaire universel des peaux et mesures anciens et modernes, contenant des tables des monnaies de tous les pays* (Anvers, 1840); William Tate, *The Modern
"A Survey of Ottoman Architectural Metrology"


9 Bernard must have been referring to the Bodleian Library of Oxford University. Three treatises of Taki al-Din Muhammad Ibn Ma'ruf exist in this library in Ms Graves 3: Rihanat al-rûh fi ṭarrâm al-dâ' permutation d'objets, 402; Kitâb al-tâmir al-yâni'î ch fi katu' al-dâ' al-yâmi'î ch, 50-57; al-Násib al-mukhtashâfîn fi'tima al-järî wa 'l-makhabîhî, 39-42v. Unfortunately, we have not yet had the chance to study these manuscripts, but I expect that the information provided by Bernard appears in one of them. John Greaves had visited Istanbul in 1637-38, Egypt in 1638, Italy in 1659, and went to Oxford in 1640 as Savilian Professor of Astronomy. It would thus be reasonable to assume that Graves had acquired Ibn Ma'ruf's treatises while he was in Istanbul.


11 When 190 is divided by 44.5, it gives the value of μ as 2.9, which is a very crude approximation. Though it seems rather unfitting for a scientist like Ibn Ma'ruf, it recalls the one used by Bahâ' al-Dîn al-Amîlî (1547-1629), a prominent mathematician whose works enjoyed great popularity in Anatolia, Persia, and India. In Hûlusî bâhi'âb, the value of μ that al-Amîlî used in calculating the volume of the sphere effectively corresponded to 2.9; see Adolf P. Ushkerni, Les mathématiques arabo-VIIe-XVe siècles, trans. M. Cazenave et K. Jarchée (Paris, 1976), pp. 107-8.

12 The value of the English yard of 36 inches, 91.44 cm, declared to be legal in 1898 was true for the yard dating from the times of Henry VII (1457-1509) and Elizabeth (1533-1603) and the standard bed in the Guildhall, with negligible variations; see G. Strasser, The Tease, the Yard and the Metre: The Struggle for a Universal Unit of Length (Heerbrugg, 1974), p. 8. In converting Bernard's measurement of the module into its metric equivalent, therefore, the English inch of 2.54 cm may confidently be used.

13 Ebliva Çelebi, Ebliva Çelebi Seyahatnamesi, trans. Zuhuri Danisman, 10 vols. (Istanbul, 1970), 1:15. The difference of "a span" between the circumferences of the two domes gives an impression of vagueness, and thus seems to reflect the insensitivity of the mathematicians when they encountered the two nearly equal but irregular circular domes. It is interesting to note that Ibn Ma'ruf did not express any ambiguity in his measurement. It may be speculated that he took the circumference by playing with the value for μ bordering the tolerance limits of approximation (see above n. 10), so as to substantiate Sinan's claim: if the circumference of the Selimiye Mosque is taken as 130 + 4 archs, then it corresponds to a diameter of 31.30 m which fits the actual dimensions nicely.

14 The quotation is taken from Henri Sauvage, "Matériaux pour servir à l'histoire de la numismatique et de la métrologie musulmane," Journal Asiatique, ser. 8, 9 (1866): 529.

15 John Greaves, Miscellaneus Works of Mr. John Greaves, Professor of Astronomy in the University of Oxford, publ. Thomas Birch, 2 vols. (London, 1737), 2:233. This particular information was first published in John Greaves, Discourse of the Roman Font and Donarius (London, 1647). For the length of the English foot, 30.48 cm, see above n. 11. Gonzales draws a length of 12.35 cm for his module C and says: "C is a quarter of an ell [i.e., cubit] of Cairo used for measuring all the fabric produced in Egypt. It is called the 'pè' of Cairo," This measure is also known as [the one of] the Nile. During the period of the Nile's overflow, the popular daily expression is: so many pè washed in the Nile"; Antonio Gonzales, Hierosolymica reser, 2 vols. (Antwerp, 1675), 2:84-85.

16 Muhammad ibn Ahmad ibn Ilyas, Journal d'un bourgeois du Caire, trans. Gaston Wict, 2 vols. (Paris, 1900), 2:400. In spite of Suleyman I's efforts, the pre-conquest Egyptian measures remained in use in the markets until the adoption of the metric system. As Egyptian metrology is beyond the scope of this study, the details are not provided.


18 Ibn Ilyas, Journal, 2:400, 427, 453. The dihir Istanbul, which was added to Egyptian metrology possibly in the seventeenth century, does not correspond to the one sent by Suleyman I in 1520. Gonzales draws one-fourth the cubit of 66 cm as module-A, and says: "A is a quarter of the Constantinople ell which is used in measuring all sorts of fabric, such as silk, damask, satin, velvet, and others, coming from Italy and other Christian countries"; Gonzales, Hierosolymica reser, 2:84-85. The mean of the recorded values of the Egyptian dihir Istanbul in the eighteenth- and nineteenth-century sources cited in n. 5 is 67.7 cm. In value in 1520 is thus probably lower than, or around, 67 cm. Such a value would yield, according to Ibn Ilyas's reports, a Hashimi cubit shorter than or, at most, equal to the "black cubit" (nearly 54 cm); see below n. 19. On the other hand, Abû'l-Hasan al-Mâsârî (975-1058) and other contemporary Arab authors defined the small Hashimi cubit, or Bâlî as "214 digits longer.
than the black cubit" (Sauvage. "Materiius," pp. 492, 495, 497, 501). Abu Tahir ibn al-Iyab (fourteenth century) draws one-third of this cubit in his manuscript, it corresponds to a cubit of 57.5–57.6 cm; ibid., pp. 503–4. The ell of 60 cm of which Gonzales draws the quarter-module B probably constituted the upper limit of this cubit; Gonzales. *Hermasdelmske reise*, 2:84–85. It is therefore impossible that the džėl Istanbullı originated from the cubit of Istanbul to which Ibn Iyab refers.

18. Since the occupation of Egypt by Napoleon (1789–1801), the Nilometer on Rauda Island in Cairo has been studied by many scholars. Papper's work, which provides the most comprehensive historical analysis, is the one used for this study; William Papper. *The Cairo Nilometer* (Los Angeles, 1951), pp. 102–6.

19. The mean lengths of the cubits engraved on the pre-Arab Egyptian Nilometers range between 52.0 and 55.5 cm; Henry G. Lyons. The Cadastral Survey of Egypt. 1892–1907 (Cairo, 1908), p. 54. Lepsius obtains a mean length of 52.5 cm for the ancient Egyptian royal cubit; Carl R. Lepsius, *Die Längenmaße der Alten* (Berlin, 1884). Petrie confirms this by determining the length of the cubit on the extant rods to be 52.6 cm and by deriving from the pyramids and other existing buildings a unit length of 52.5 cm (Flinders Petrie, *Ancient Weights and Measures* [London, 1926]). It appears that the Ptolemaic reform of the Egyptian system had increased it to 55.5 cm (see below n. 49). Contemporary Arab authors tell us that the "black cubit," as they call it, used in measuring the height of the Nile was introduced by Caliph Harun al-Rashid (786–809), or Caliph al-Mansur (754–75), using as measure the length of the forearm of a black slave (Sauvage. "Materiius," pp. 491, 494, 497, 501, 507). Apparently, the ancient Egyptian cubit had again been slightly increased during the Abbasid era to around 54 cm. The same length recorded by Gonzales as "the measure of the Nile" testifies to the continuity of this measure in the seventeenth century.

20. The new cubit of 36.07 cm is confirmed by Le Père who took part in the research team of the French expedition in Egypt in 1799–1800. He states that when the guardian (shaykh) of the Nilometer was asked for the measure which he used, he showed a scale which was called the "cubit of the Nile" which measured, in terms of the French pied de roi, 15 pouces 4 lignes: Le Père. "Mémoire sur la Vallée du Nil et le Nilometer de l'Île de Roudah," *Description de l'Égyptie*, 2d ed. (Paris, 1829), 18:611. This measurement corresponds to 36.08 cm (for the length of the pied de roi, see below n. 24).

21. "Uthman al-Muhtadi. Hadjiyis al-mushadi. Ýr im al-handasa wa al-muṣābaka wa ramy al khamira wa kof al-lughm. (The present of the guided; a work on geometry, surveying, the throwing of missiles, and the digging of mines) Princeton Library, Garret Collection, ms. 162 L; al-Muhtadi (the convert) was the interpreter in the fortress of Bulgar. For the traditional use of hadım in Ottoman metrology, s.v. "Arşın," *İslam Anshblopesis*, 1: 616. For the usage of the same unit in the late nineteenth century, see Salih Zeki, *Kâmrâ-i riyaşat*, 2 vols. (Istanbul, 1315 [1897]), 1:59. For the extant specimens of hadım, see n. 29.

22 Baron François de Tott, *Memoirs of Baron de Tott*, trans. from French ed. 2 vols. (London, 1785), 2:151–54. Baron de Tott unequivocally gives the name of the Turkish ell as pic. As far as we know, the measuring units were referred to interchangeably as arşın and şirî in the contemporary Ottoman sources. The term pic — derived from pıçıs (cubit in Greek) — was used by many European writers in referring to the measuring units of the Levant. As Baron de Tott appears particular about using the local terminology, it gives the impression that pic was another common word among builders, but in fact it never surfaces in Ottoman literary sources.

23. Each builder was carrying a measure of double arşın: assuming that Ottoman architects executed their designs on paper incised with modular square grids, this information suggests a design module of two measuring units. For extant Ottoman plans, see Gürcü Necipoglu-Kafadar. 'Plans and Models in 15th- and 16th-Century Ottoman Architectural Practice,' *Journal of the Society of Architectural Historians* 45 (1986): 224–43.

24. French metrology provides us with interesting information for comparison with Ottoman metrology. It is therefore studied here in more detail than is necessary for determining the length of the French foot (pied de roi) that Baron de Tott used in the third quarter of the eighteenth century.

Pied de roi is divided into 12 pouces (inches) or 144 lignes (lines), and 6 pieds make a toise (fathom). It served as the royal standard measure in France until it was, after a long struggle following the Revolution, finally abolished and replaced by the meter in January 1, 1840. It was then measured as 32.47 cm; Strasser, *The Toise*, pp. 4–7. In March 1687, Abbé Picard restored the value of the standard toise kept in the Chatelet, "which had become 5 lignes too long through constant usage and wear"; ibid., p. 2. It could not have been the standard measure which had elongated, but presumably the units in current use proved to be slightly shorter when measured against the standard. Responding to the socioeconomic conditions of the early-modern era in France, apparently public measuring units gradually but by unnoticeable increments became shorter. At any rate, the masons were not happy with this change. Proudly claiming that their measure, the toise de Charlemagne, was the true standard, they refused to comply with the new shorter one. In order to resolve the dispute, in October 1667, the long gallery of the Louvre was measured using both standards, and the comparison showed that the toise of the masons exceeded the new one by 4.5 lignes. The masons were ordered to bring their measure into line with the new toise de Chatelet (Armand Machabey, *La métrologie dans les musées de province et sa contribution à l'histoire des pieds et mètres en France depuis le treizième siècle* [Paris, 1902], pp. 91–33). It seems certain, however, that the toise de Charlemagne of the masons represented the unreformed toise de Chatelet and the latter was not in reality elongated. The value of the standard pied de roi before 1667, therefore, was 32.65 cm. Documentary evidence from 1594 tells us that the standard was kept at the Chatelet; at the time and suggests it had been there long before (Machabey, *La métrologie*, p. 42). The masons’ claim that their standard was the true measure of Charlemagne (742–814) was not unfounded. In the early seventeenth century, Marquardus Freher informs us that the iron rod kept in the chamber of the Electors Palatine had a silver inscription on it read-
ing, Carolus Impr. fossis cubita suo facere jussa mensuram suam (Paucon, Métrie, p. 780). The length of the rod he gives, in terms of the Leiden foot (31.4 cm), as 6 fuss (foot) and 3 toll (inch) again yields a value of 32.7 cm for the pied de roi. It can thus be traced back to 789, the date of Charlemagne’s reform of weights and measures.

The French cloth merchants’ measure, the aune, presents a different picture. The standard aune kept in the Bureau of Merchants, which still exists, measures in terms of the reformed pied de roi as 3 pieds 7 pouces 10 lignes, that is, 118.81 cm. The engraved date of this standard is 1554. The edicts of both Henri II (in 1557) and of François I (in 1540) fixed the length of the very same standard as 3 pieds 7 pouces 8 lignes (Machabey, La métrie, pp. 34–35). This definition of the aune in the sixteenth century yields 32.65 cm for the value of the pied de roi, thus confirming its established value before 1667. More importantly, it shows that the aune and the pied de roi belonged to different metrological systems. The word aune was derived from the Latin uncia. Roman metrology was quite standardized and well documented. Through immaculate research by many scholars, mainly on extant units, the length of the Roman foot has been established as having been between 29.2 cm and 29.7 cm, and most respectfully at 29.6 cm. When the length of the aune is divided by 4, the foot corresponds to 29.7 cm. Given the historical context of early medieval Europe, it seems almost certain that the aune came from the Roman unit a of 4 feet.

In accordance with this study, the length of the pied de roi that Baron de Tott used in measuring the Ottoman builder’s cubit is taken as 32.47 cm.


27. “The pic of masons, or the great pic, is equal to two pieds four pouces three lignes, or 76.5 cm,” Guillaume-Antoine Olivier, Voyage dans l’Empire Ottoman, l’Égypte et la Perse, 6 vols. (Paris, 1801–7), 1:29. Olivier visited Istanbul in the early 1790’s. Since he and Baron de Tott give the same measurement, it must have been the standard value for the builder’s cubit until 1794–95.

In addition to the builder’s cubit, the common cubit (68 cm). and the endåz (65 cm). Olivier gives the length of a cubit measure used in artillery: around 70.5 cm. Baron de Tott, who himself was an artillery officer and was involved in the military reforms in Istanbul between 1768 and 1774, does not mention this last measure. We infer from his silence that it was not in use until 1774. Paucon gives two values for the “great pic of Istanbul,” 70.8 cm and 70.9 cm, which appears to be the same cubit measure (Paucon, Métrie, pp. 773, 782). Paucon’s book was published in 1780. It can thus be suggested that this cubit measure was introduced in Ottoman metrology sometimes between 1774 and 1780. In the nineteenth-century sources cited in n. 5, this cubit was recorded with a fixed value, 70.9 cm, under the name Halabi (from Aleppo) and was mentioned that it was used in surveying. It was not, however, included in the official list of the traditional measures that existed when the metric system was first adopted in 1869 (see below, n. 28). From this short-lived but significant Ottoman measure, comes the distorted Turkish saying used today to challenge someone who is boasting: Halebi [i.e. endåz] var ya mescid-i serif (If the [front]-Aleppo is there, the mosque is here).

28. Empire Ottoman, règlement et tables pour la conversion de poids et mesures (Constantinople, 1870), p. 5. It was measured more precisely as 75.7738 cm.

29. The architect’s cubit of Selim III is preserved in Istanbul Technical University, the Research Centre for the History of Science and Technology, inv no. 7. It is made out of a single piece of ebony and has no decoration. The cross-section is a square of 16 by 16 mm. The extant specimens of the Ottoman architect’s cubit that I have had access to are as follows: (a) Topkapı Sarayı Müzesi, 3/3913: made of ebony with ivory and mother-of-pearl inlay; folds into two sections: divided into 12 digits; the kadem, measures 37.8 cm (argun: 75.6 cm). (b) Topkapı Sarayı Müzesi 27/96: made of bronze; folds into four sections: divided into 24 digits; the kadem, measures 37 cm (argun: 74 cm). (c) Topkapı Sarayı Müzesi 27/67: made of bronze with ivory inlay; one piece but the metal mounts at both ends are missing; divided into 4 palms, palms are subdivided into 6 digits; when the average length of a digit (31.53 mm) is assigned to the end ones, measures 75.7 cm. (d) Topkapı Sarayı Müzesi 27/73: manufactured in France, made of wood in square section; one piece, different scales on four sides: (i) divided into 30 English inches, measures 76.2 cm; (ii) metric divisions of a total of 76 cm; (iii) divided into 12, measures 75.8 cm. (e) Topkapı Sarayı Müzesi 27/102: made of brass; folds into four sections: divided into 24 digits; the kadem, measures 37.8 cm (argun: 75.6 cm). (f) Topkapı Sarayı Müzesi 27/378: made of bone with silver mounts at the ends; divided into two sections: divided into 12 digits, the eleventh digit is subdivided into 12: the kadem, measures 37.9 cm (argun: 75.8 cm). (g) Topkapı Sarayı Müzesi 27/4742: made of wood with ivory and mother-of-pearl inlay; folds into two sections with a silver hinge; divided into 24 digits; measures 75.8 cm. (h) Türk ve İslam Eserleri Müzesi, Etnografya, 2066: made of wood, folds into four sections; divided into 12 digits; measures 75.8 cm. (i) My own collection, from Göynik: manufactured in England, made of wood, folds into four sections; divided into 24 digits; measures 75.8 cm.

The discrepancy between specimen b and the others, whose deviations from the standard value of 75.8 cm are negligible, is noticeable, suggesting that it may date back to a period earlier than 1794–95.


31. Cal’er. Rūsal-i mi’mârîye, p. 84. For the information concerning Matrakçı’s work, see Adivar, Osmanlı Türkîrâne-i İlim, p. 86. For Muhîl al-Din’s work and Mülâbbâb hatûs, see Inalik, "Ottoman Metrology," pp. 193–295. For the anonymous arithmetic handbook in Greek, see Herbert Hunger and Kurt Vogel, Ein byzantinisches Rechenbuch des 15. Jahrhunderts (Vienna, 1963). Inalik dates this work to around 1500, but Hunger and Vogel consider it late Byzantine: it cannot
reasonably be late Byzantine, however, as the decimal fractions, which were discovered in 1427, could not have been in general use in the Ottoman lands before 1453. Of the 19 copies of *Myfiik al-babāb* that I have located, 10 were found in Istanbul; Alpay Özdural, "Givaseddin Jemshid el-Kashi and Stalactites," *Middle East Technical University Journal of the Faculty of Architecture*, 10 (1990): 44. Decimal fractions were rediscovered by Bruges and introduced in Europe in 1585; s.v. "al-Kashi," J. Vernet, *Encyclopedia of Islam*, 2rd ed., 4: 704.

32. Cafer is actually speculating when he states that the thirty-second part of the common cubit, *girsh*, was derived from commercial calculations, which were based on the division of the *ākāb* into 32 *mānībīs*. The hexadecimal scale of a foot measure dates back to ancient times. The reason for this, it seems, was the human habit of folding a piece of cloth, which was the most common item to be measured, successively into halves. The double hexadecimal scale of the Ottoman common cubit apparently followed this age-old tradition.


34. Empire Ottoman, *poids et mesures*, pp. 2–5.

35. "At Constantinople from a Jew sent on purpose: 31/32 of the Constantinople great *pike* maketh the small *pike* of Constantinople. . . The greater Turkish *pike* at Constantinople is 2200 [of the 1000 parts of the English foot]" (Greaves, *Miscellaneous Works*, 2:505). For the value of the English foot, see above n. 11. We may deduce from Greaves’ account that the *endase*, the smaller unit used for measuring silk and other expensive cloth, was originally defined as one-half *girsh* shorter than the *dimme girsa’s* which was divided into 16 *girsh*. It has to be noted also that Greaves, like Baron de Tott who was careful to use local names, was referring to Ottoman cubits by their Greek appellation.


37. Bartolomeo Di Pasi, *Tarifia de peo e measure corrispondenti dal Levante al Ponente, da una terra all' altra, e suole le peste del mondo*, con la notizia delle rote che se trazzeno da una paese per il l'altro (Venice, 1521; 1st ed. 1503). Anonymous, *Tarifia geste de pez e mesure d’Asse, Africa, & Europa* (Genoa, 1641). According to the preface written by Bartolomeo de Benedetti, *Tarifia geste* was published earlier by Geronimo Zoto, but the name and the dates of the author are unknown. Based on the internal evidence, I would date it to the beginning of the sixteenth century. Apart from these two, several other medieval merchant’s manuals written by Florentine and Venetian authors in the fourteenth and fifteenth centuries provide similar correlations between Italian, other European, and Mediterranean metrologies. Francesco Balducci Pegolotti, *La pratica della mercatura* (around 1450), ed. Allan Evans (Cambridge, Mass., 1936); Anonymous, *Tarifia soet noticia dy pese e mesure di luoghi e teri che s’adova mercantia per el mondo* (after 1345 well into the second half of the century), publ. University of Pavia (Venice, 1925). Giovanni di Antonio da Uzzano, *Pratica delle mercatura* (1442), publ. G.F. Pagnini in *Della decima e di altre mercanzie imposte dal comune di Firenze, della moneta e della mercatura de’ Fiorentini fino al secolo XVI*, vol. 4 (Lisbon and Lucca, 1766); Giorgio di Lorenzo Chiarini, *Libro che tratta di mercantia e usanze de’ fiorenti* (1458, the earliest ms.), ed. Franco Borlandi (Turin, 1898). All these manuals provide us with rich information concerning the measuring units used in the countries around the Mediterranean and the Black Sea. The problem with them is how to convert this valuable information into methodologically safe metrological data. The correlations cited in them are based on the unit of one of the major Italian cities, but unfortunately, metrological histories of these cities are not well enough established to allow us confidently to assign the metric value of that particular unit at the time when the manual was written; see Ronald E. Zupko, *Italian Weights and Measures from the Middle Ages to the Nineteenth Century* (Philadelphia, 1981). Mostly, the last pre-metric values of these units are regarded as fixed throughout their history, and unknown quantities of the correlations are calculated accordingly. What we have observed so far in this study demonstrates strikingly that that may not necessarily be the case. As a methodological safeguard against that possibility, I have devised a procedure to be applied to these fourteenth-, fifteenth-, and sixteenth-century manuals. I selected the measuring units of the Italian and other European cities that appear in these manuals and calculated their mean values recorded variously in the late metrological sources cited in nn. 5, 14. In doing so, I also had the opportunity to examine the trends of the units in the major cities in the period by the latter sources. Had there been alterations during the sixteenth and seventeenth centuries, the period that is not covered by the available sources, I reasoned, they would not have taken place in all these units, and the rate could not have been the same in all cases. Therefore, by first feeding the obtained mean values of the late centuries in the tables of the intrinsically approximate correlations cited in the Italian manuals and calculating these through iteration until they all agree satisfactorily among each other, the information can be converted into fairly safe metrological data. These manuals, however, are not of the same nature. I treated the correlations in Di Pasi’s work, which wholly contains firsthand information, in one table. The anonymous author of *Tarifia generale* gives firsthand information for Genoese measures but relied otherwise on previous works. I therefore dealt with only the firsthand information in a separate table. The authors of *Tarifia soet noticia, Pratica della mercatura, and Libro che tratta de’ usanze* of Pegolotti’s *Pratica*. Hence I chose to tabulate the information from the last four together. The results obtained revealed that in most cases the alterations were either quite small or practically nonexistent. Then, I assigned the values thus obtained to the units in the correlations between them and the unknown ones that are to be calculated in this study.

38. Di Pasi, *Tariffe de pez e measure*, pp. 215r, 123v, 124v, 156r, 138v, 145v. According to the procedure outlined in n. 37, the values of the *braccio* of wool and silk of Venice are calculated respectively as 67.0 cm and 63.1 cm. The recognized values of these in the sources after 1840 were 68.34 cm and 65.87 cm. To add to our confidence, the ratio between the obtained values answers precisely the original definition: the *braccio* of wool is longer by a sixteenth part than the *braccio* of silk. For comparison with the definition of the Ottoman *endase*, see above n. 35.

39. *Tarifia generale*, p. 32. The *palmo* of Genoa is calculated as 24.7 cm in accordance with the procedure explained in n.
37. It had retained practically the same value until it was replaced by the meter.

40. For Caifer's life, see Caifer, Risade m'uiyya, pp. 5-6. For a comparison of Ottoman cloth merchants' presumed claim with French masters' claims, and for the French eau and Roman ala, see above n. 24.


42. The correlations and related facts involved in the calculations concerning this evaluation in accordance with the procedure defined in n. 37 are too complicated to be described here. Byzantine metrology is not of primary concern to this study.


45. Alexander, Universal Dictionary, p. 22. Some of the nineteenth-century authors record another type of Turkish mile which ranges between 1,667 and 1,670 m.

46. Avaz Kınınnâmesi (1274 [1858]), article 131. For numerous citations of the traditional definition of dönüm in earlier codes, see Hadiye Tunicer, Osmanlı Imparatorluğu'nda toprak hakuku, arazi kanunları, ve kanun aşklamaları (Ankara, 1962); Ömer L. Barkan, XV ve XVI asırlarda Osmanlı Imparatorluğu'nda ziraat ekonomisinin hakuki ve mali esasları (Istanbul, 1943).

47. Schilbach refers to the stremma of 1,270 m² in Greece as "the Turkish dönüm" and mentions that it remained in use in Turkey as well until 1874; Erich Schilbach, Byzantinishe Metrologie (Munich, 1970), pp. 73-74. According to Tate's Modern Cambo, p. 145, the old stremma of Greece is equal to 1,270 m², and the Turkish measures were used in use until the introduction of the metric system.


49. Hero of Alexandria, Codex Constantinopolitanus Palatii Veteris No. 1, ed. and trans. E.M. Bruins, 3 vols. (Leiden, 1964), 3:5. While discussing the measurement of timber, Hero says: "The ell is 6 palms, 24 fingers, 1/2 Roman feet, 1 1/3/2 or 1 3/4 Italian feet... And the Poitevin foot has to the royal ell in linear measure a ratio as 2 to 3"; ibid., p. 176. We thus understand that the Poitevin foot and the Philietrical foot were different terms for the same measure in Egypt. and the former was commonly used among carpenters. Didymus describes the Poitevin foot which stands to the Roman foot as four palms to three and a third — that is, the ratio 6:5: Friedrich O. Hultsch, Metrologorum scriptorum rerum variorum, 2 vols. (Leipzig, 1864), 1:180. It is obvious that Hero was using Italian as a synonym for Roman.

50. One-half the stoic ell, i.e. the Philietrical foot, recalls one-half the Ottoman builder's cubit, i.e. the kadem. The use of the latter in excavations and wells, it may be speculated, perhaps reflects the relation of the former to the Nilometer cubit. This possibility may also help us to explain the coincidence of the slightly increased version of the Ottoman kadem in 1923 matching practically two-thirds of the Arabic "black cubit," a slightly increased version of the Poitevin Nilometer cubit in the Cairo Nilometer.

51. For a brief discussion of this point, s.v. "Misâha" (H. Schirmer), El, 1st ed., 3:519. Kidson convincingly argues that mainly through the works of Roman land surveyors (agrimensores). Roman metrology as described by Hero had been transmitted to the Middle Ages. He emphasizes that the 148-cent nave de Notre Dame of 4 Philietrical feet was habitually used by French masters until it was replaced by the toise de Charlemagne in the thirteenth century; Peter Kidson, "Systems of Measurement and Proportion in Early Medieval Architecture," 2 vols., Ph.D. diss., London University, 1956, passim. As we learn from Baron de Tott, Ottoman builders customarily used a rod of double arm (see n. 23). According to our evaluation, it corresponds to 142.4 cm in the early Ottoman period. If Kidson's and my arguments are true, then the measuring rods of early medieval French masters and of early Ottoman builders had virtually the same length and plausibly the same source.