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Read by the Author

New Findings in Haṛappan Town Planning and Metrology

Michel Danino

IT is a privilege to contribute to a Festschrift to Dr S.R. Rao, who left his mark on Indian archaeology after Independence. His excavations at Lothal in the 1950s represented a turning point in our understanding of the Haṛappan civilization beyond the Indus Valley, and in several ways my paper is intimately connected to them. Its starting point, however, is Dholāvīra.

Dholāvīra's Plan and Proportions

Dholāvīra (23°53''10'' N, 70°13' E) is probably the most spectacular Haṛappan site to be seen after Moheṅjo-dāṛo, and, at 48 ha, the second largest in India (after Rākhīgaṛhī in Haryana). Discovered by the late Jagat Pati Joshi in the 1960s on the Khadir island of the Rann of Kachchh, it was excavated in the 1990s under the direction of R.S. Bisht of the Archaeological Survey of India (ASI). The Haṛappans' motivations in setting up this large city in such a harsh and forbidding environment must have been intimately related to access to raw materials, craft production and trade. There is evidence that the Rann of Kachchh was navigable in Haṛappan times, which would have given Dholāvīra access to the sea.[1] As a regional capital, Dholāvīra must have exerted a measure of control over the hundreds of smaller Haṛappan sites dotting Kachchh, Saurashtra and mainland Gujarat. It flourished during the Mature Haṛappan phase, i.e. between 2600 and 1900 BCE.

Even if the climate was probably slightly more congenial than it is today, the establishment of such a city in this location is a feat of planning, engineering, labour control and execution, especially in the field of water harvesting and management: Dholāvīra's colossal water structures, covering some 17 ha and often interconnected

[1] Danino 2010a: 165 (and references cited).

through underground drains, were the *sine qua non* of the city's survival through the year.

Like most Haṛappan sites, Dholāvīra followed a strict plan, but one of its kind with multiple enclosures. While Haṛappan town planning is often based on an acropolis/lower town duality (as at Moheṅjo-dāṛo and Kālibaṅgan), Dholāvīra's plan (*fig*. 9.1) is triple: an acropolis or upper town consisting of a massive "castle" located on the city's high point and an adjacent "bailey"; a middle town, separated from the acropolis by a huge ceremonial ground; and a lower town, part of which was occupied by a series of reservoirs (terms such as "castle" and "bailey" are those of the excavator).

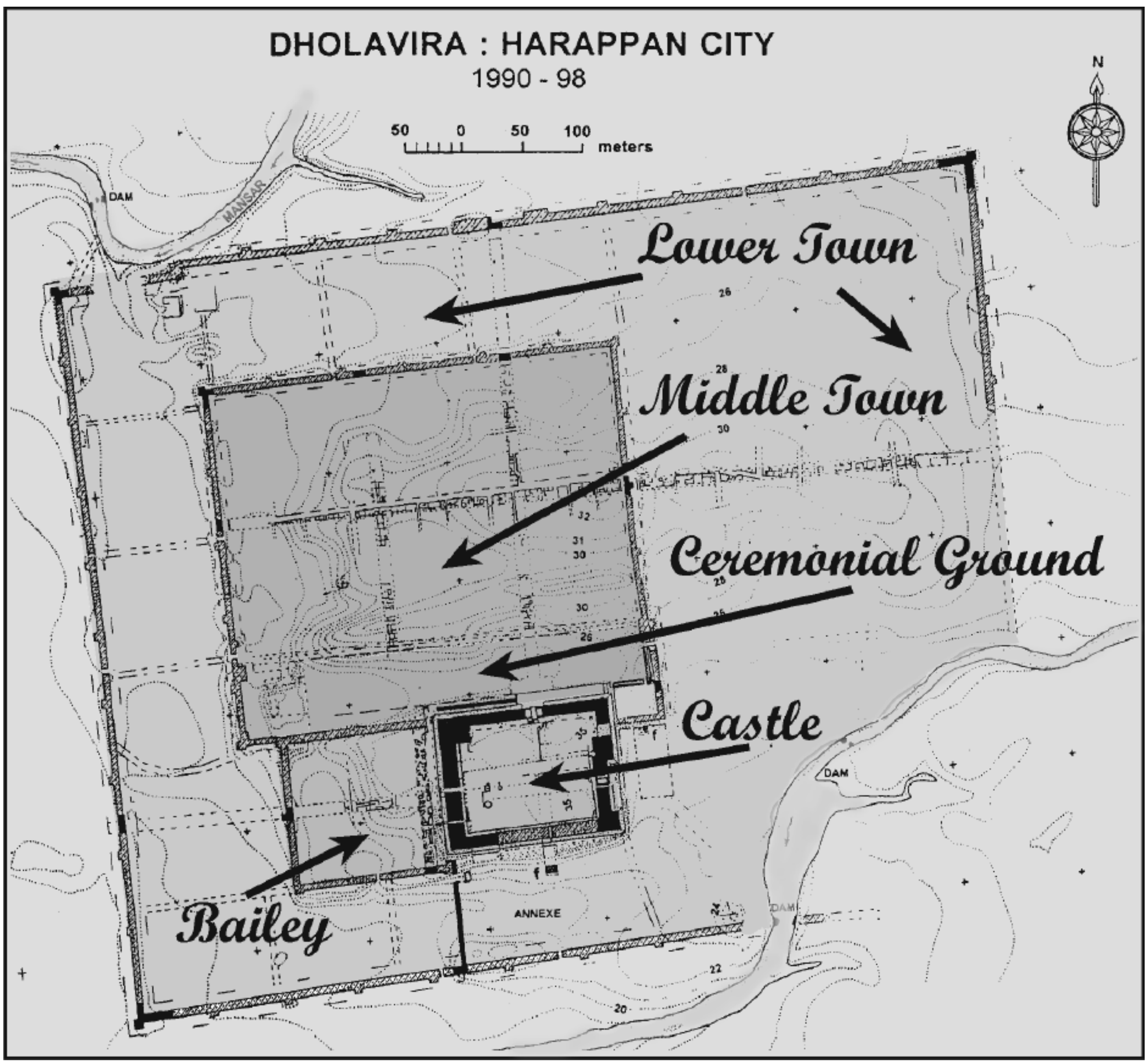

fig. 9.1: Plan of Dholāvīra (adapted from Bisht 1999)

Table 9.1: Dholāvīra's Dimensions

Dimension	*Measurement (in metres)*	
	Length	*Width*
Entire city	771.1	616.85
Middle town	340.5	290.45
Ceremonial ground	283	47.5
"Castle" (inner)	114	92
"Castle" (outer)	151	118
"Bailey"	120	120

A mere look at the plan suggests a complex conceptual background. Can we make some sense of the concepts and rules Dholāvīra's urban architects followed? To do so, we need to study the dimensions of the various fortifications, which were precisely measured by the ASI team. Table 9.1 summarizes them,[2] with a maximum margin of error of 0.5 %.[3] Importantly, the three longest dimensions have since been confirmed by Global Positioning System (GPS) readings.[4]

It became immediately clear to the excavator that these dimensions obeyed precise ratios or proportions. Bisht highlighted some of them as follows (I have added in parentheses the margins of error calculated on the basis of Table 9.1 and rounded off to the first decimal):

1. The **city's** length (east–west axis) and width (north–south) are in a ratio of **5 : 4** or 1.25 (0.0 %, a perfect match).
2. The "**castle**" also reflects the city's ratio of **5 : 4** (0.9 % inner, 2.4 % outer).
3. The "**bailey**" is square (ratio **1 : 1**).
4. The **middle town**'s length and breadth are in a ratio of **7 : 6** (0.5 %).
5. The **ceremonial ground**'s proportions are **6 : 1** (0.7 %).

All but one ratios are verified within 1 %, an excellent agreement considering the irregularities of the terrain. In two papers,[5] I worked out a few other important ratios at work in Dholāvīra, some of which would have been chosen by the town planners in

2 Bisht 1997, 1999, 2000.

3 Bisht 2000: 18.

4 Danino 2010b.

5 Danino 2005, 2010c.

order to define the whole city geometrically, others following as consequences of those initial choices. The principal ratios are summarized in Table 9.2 and *fig*. 9.2. Not only are the margins of error very small, but the repetition of ratios 5 : 4 and 9 : 4 cannot be accidental.

Table 9.2. Dholāvīra's Ratios and Margins of Errors

Dimensions	*Ratio*	*Margin of Error* (%)
Entire city*	5 : 4	0.0
"Castle", inner*	5 : 4	0.9
"Castle", outer*	5 : 4	2.4
"Bailey"*	1 : 1	0.0
Middle town*	7 : 6	0.5
Ceremonial ground*	6 : 1	0.7
Castle's outer to inner lengths**	4 : 3	0.7
Middle town's length to castle's internal length**	3 : 1	0.4
Middle town's length to castle's outer length**	9 : 4	0.2
City's length to middle town's length**	9 : 4	0.6
Middle town's length to ceremonial ground's length**	6 : 5	0.3

* Proposed by R.S. Bisht, ** Proposed by Michel Danino.

Dholāvīra's Master Unit of Length

How were Dholāvīra's town planners able to impose such a set of precise ratios and dimensions on the ground? Two assumptions appear reasonable at this stage: (1) they must have used a standard of length; and (2) they chose integral (or whole) multiples of this standard for as many of the main dimensions as possible. I propose that there is a simple way to calculate the main linear unit used at Dholāvīra.

Let us call it "D" for Dholāvīra. Elsewhere,[6] I used a simple procedure to calculate the largest possible value of D that will result in most of the city's dimensions being expressed as integral multiples of D. The procedure, briefly put, consists in algebraically expressing the smallest dimension in our scheme (i.e. the average width of the castle's western and eastern fortifications) as a multiple of the unknown unit D (or nD, n being an integer); then, using all available ratios, to express all larger

[6] Danino 2010c.

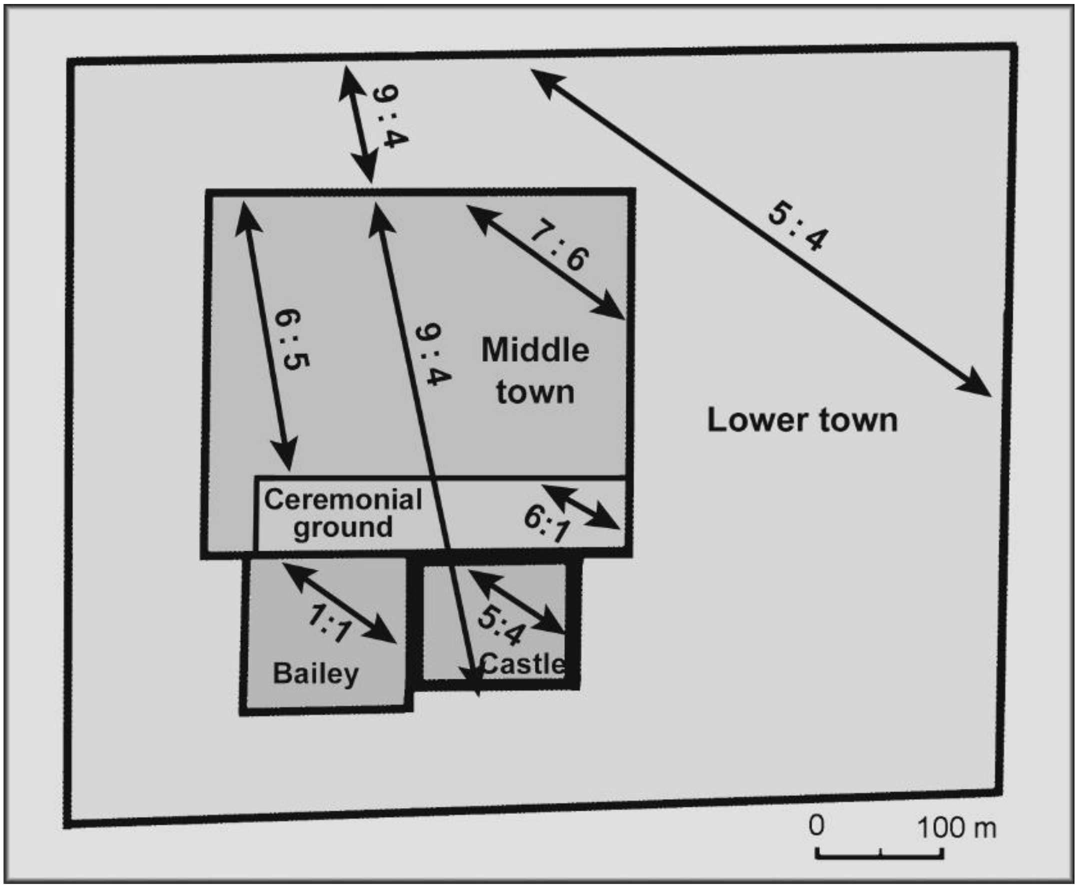

fig. 9.2**:** Main ratios at work in Dholāvīra's plan

dimensions in terms of nD. We find, of course, that a few dimensions are not integral but fractional expressions of nD. To make those fractions disappear, we choose "n" as the least common multiple of their denominators. It turns out that with n = 10, all fractional results disappear, except one. Going back to our initial formula, the width of the castle's western and eastern fortifications, which we expressed as nD, is now 10 D. Bringing into play the proportions listed above, we can express all but one dimensions as multiples of D. *Fig*. 9.3 summarizes the findings. (The exception is the middle town's width, but this is normal: if the middle town's length is, as produced by these calculations, 180 D, with a ratio of 7 : 6 between them, the width cannot be an integral multiple of D; it will be about 154.3 D. In reality, at 290.45 m, it is almost 153 D.)

We now only need to determine the value of D, which is simply derived from the city's length: if 771.1 m = 405 D, then **D = 1.904 m** or 190.4 cm, which we may round off to **1.9 m**.

Starting from this value and calculating the theoretical dimensions backward using *fig*. 9.3, we can compare them with the actual dimensions. Table 9.3 lists the results, as

Table 9.3: Comparison Between Theoretical and Actual Dimensions

Dimension	*Length (in Terms of Unit D)*	*Theoretical Measurement (Metres)*	*Actual Measurement (Metres)*	*Margin of Error (%)*
Lower town's length	405	771.1	771.1	0.0
Lower town's width	324	616.9	616.85	0.0
Middle town's length	180	342.7	340.5	+ 0.6
Middle town's width	154.3	293.8	290.45	+ 1.1
Ceremonial ground's length	150	285.6	283	+ 0.9
Ceremonial ground's width	25	47.6	47.5	+ 0.2
Inner castle's length	60	114.2	114	+ 0.2
Inner castle's width	48	91.4	92	– 0.7
Outer castle's length	80	152.3	151	+ 0.9
Outer castle's width	64	121.9	118	+ 3.2
Bailey's length and width	63	120.0	120	0.0

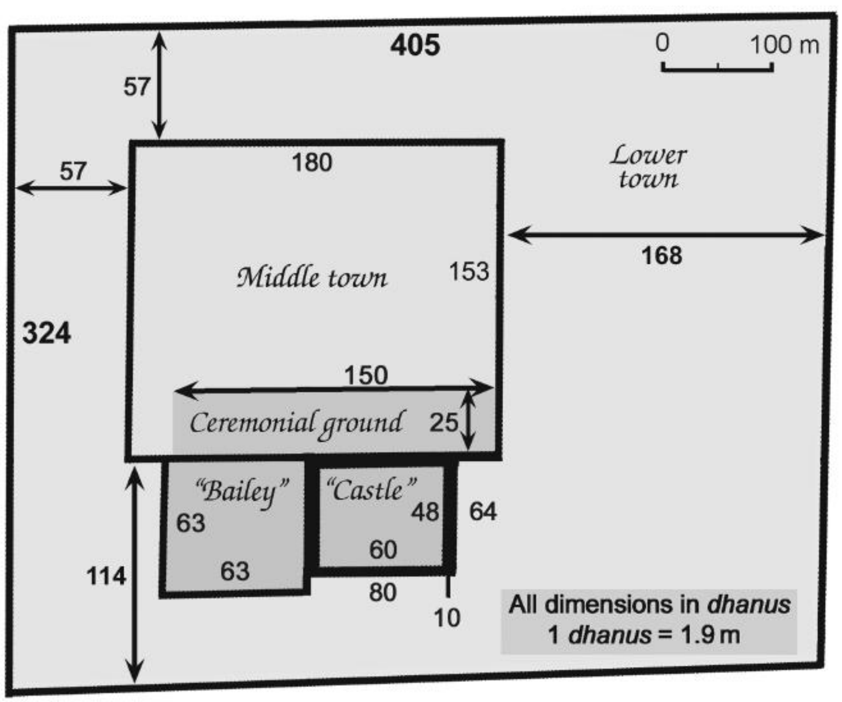

fig. 9.3: Dholāvīra's main dimensions expressed in terms of *dhanus*, Dholāvīra's master unit of length well as the margins of error between theoretical and actual dimensions. The latter are remarkably modest, 0.6 % on average (the highest being, again, in the outer dimensions of the "castle"). These almost perfect matches appear to rule out the play of chance.

Ratios in Haṛappan Settlements

For whatever reasons, Haṛappans clearly preferred certain fixed ratios to random proportions. This is visible not just at Dholāvīra but at other Mature Haṛappan sites, as the following selective list shows (in increasing order):

- **Ratio 7 : 6**, the ratio of **Dholāvīra's** middle town, is found in the dimensions of the "assembly hall", also called "pillared hall", on the southern part of **Moheṅjo-dāṛo's** acropolis, which measures "approximately 23 x 27 m".[7]
- **Ratio 5 : 4**, Dholāvīra's prime ratio, is found elsewhere in Gujarat at **Lothal**, whose overall dimensions are 280 x 225 m,[8] and **Jūnī Kuran** (just 40 km away from Dholāvīra in Kachchh), whose acropolis measures 92 x 72 m,[9] which approximates 5 : 4 by 2.2 %. It is also reflected in **Haṛappā's** "granary"[10] of 51.2 x 40.8 m (with a precision of 0.3 %) and in a major building of Moheṅjo-dāṛo's HR area[11] measuring 18.9 x 15.2 m (0.5 %).
- **Ratio 5 : 4** is repeated in other ways. At **Dholāvīra**, for instance, there are five salients on the northern side of the middle town's fortification, against four on its eastern and western sides (if we include the corner salients, their numbers grow to seven and six, which reflect the middle town's ratio). Returning to Moheṅjo-dāṛo's "pillared hall", it had four rows of five pillars each.[12] It is quite intriguing that this hall, in its dimensions (7 : 6) as well as rows of pillars (5 : 4), should reflect Dholāvīra's two key ratios!
- **Ratio 4 : 3** is visible in **Moheṅjo-dāṛo's** "granary" (also called "warehouse"): this structure is composed of 27 brick platforms (in 3 rows of 9); while all platforms are 4.5 m wide (in an east–west direction), their length (in a north-west direction)

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[7] Possehl 2003: 194.

[8] Lal 1997: 129.

[9] Chakrabarti 2006: 166.

[10] Mackay 1989: 45.

[11] Dhavalikar and Atre 1989: 195-97.

[12] Jansen 1988 : 137.

is 8 m for the first row, 4.5 m for the central row, and 6 m for the third row.[13] It is singular that both pairs (8, 6) and (6, 4.5) precisely reflect the ratio 4 : 3.

- **Ratio 3 : 2** is the overall ratio of **Kālibaṅgan's** lower town (approximate dimensions 360 x 240 m),[14] as well as of a sacrificial pit (1.50 x 1 m).[15] It is also the ratio of three reservoirs at **Dholāvīra:** one in the "castle" measuring 4.35 x 2.95 m,[16] and two larger ones to the south of the castle.[17] We find it again (within 1 %) at Moheṅjo-dāṛo in the overall platform of the "granary", which measures 50 x 33 m.[18]
- **Ratio 2 : 1** is that of **Dholāvīra's** acropolis ("castle" and "bailey" together); it is also found at **Moheṅjo-dāṛo**[19] (whose acropolis rests on a huge brick platform

fig. 9.4: A view of Dholāvīra's eastern reservoir (author's photo).

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[13] Jansen 1979: 420.

[14] Lal 1998: 119.

[15] Ibid., 96.

[16] Ibid., 43.

[17] Danino 2010b.

[18] Jansen 1979: 420.

[19] Jansen 1988: 134.

fig. 9.5: A view of Dholāvīra's SR3 southern reservoir (author's photo).

measuring 400 x 200 m), **Kālibaṅgan**[20] (acropolis of 120 x 240 m) and Surkoṭaḍā[21] (overall dimensions 130 x 65 m).

- **Ratio 9 : 4**, apart from its double presence at **Dholāvīra**, is found at **Moheṅjo-dāṛo's** long building located just north of the Great Bath, called "block 6" and measuring approximately 56.4 x 25 m,[22] thus within 0.3 %.
- **Ratio 7 : 3** is found at **Haṛappā's** mound AB in "14 symmetrically arranged small houses",[23] each measuring 17.06 x 7.31 m (nil margin).
- **Ratio 5 : 2** is that of **Dholāvīra's** colossal eastern reservoir[24] (73.5 x 29.3 m, thus with a margin of 0.3 %), *fig*. 9.4. It is also reflected, with the same high precision, in twelve rooms of Haṛappā's "granary", each measuring 15.2 x 6.1 m.[25]

[20] Lal 1997: 122.

[21] Ibid., 135.

[22] Mackay 1998: 17.

[23] Chakrabarti 2006: 156.

[24] Danino 2010b.

[25] Kenoyer 1998: 64.

- **Ratio 11 : 4** is that of the secondary rock-cut reservoir "SR3"[26] found to the south of the **Dholāvīra's** "castle", 15.5 x 5.65 m, with a high degree of precision (0.2 %), *fig*. 9.5.
- **Ratio 3 : 1** is found at **Moheṅjo-dāṛo's** "college" whose average dimensions are 70.3 x 23.9 m.[27]
- **Ratio 7 : 2** is that of **Dholāvīra's** primary rock-cut reservoir "SR3"[28] mentioned above (33.4 x 9.45 m, thus with a margin of 1 %), *fig*. 9.5.
- **Ratio 6 : 1** is reflected not just in **Dholāvīra's** ceremonial ground but in Lothal's dockyard[29] (average dimensions 216.6 x 36.6 m).

The above examples are summarized (with a few more) in *fig*. 9.6. In probabilistic terms, while lower ratios (such as 7 : 6) could be rejected as a rough approximation of 1 and therefore of little significance, the higher we rise in the scale and the less tenable such an explanation will be: the intentional use of specific proportions is indisputable, although it has not attracted sufficient attention so far. Haṛappan architects and builders did not believe in haphazard constructions, but followed precise canons of aesthetics based on specific proportions.

We can also see that Dholāvīra's ratios are not exclusive to this site but are part of a broader Haṛappan tradition of town planning and architecture, whose conceptual foundations remain poorly understood.

Dimensions in Haṛappan Settlements

Ratios apart, we come across many dimensions of structures in Haṛappan settlements that can be expressed as integral multiples of our proposed Dholāvīra unit D = 1.9 m. A few examples are given in Table 9.4, while *fig*. 9.7 illustrates the case of Moheṅjo-dāṛo's acropolis.

While every single dimension cannot be expected to be a whole multiple of D, it is striking enough that so many should turn out to be. This makes a strong case for Dholāvīra's unit to have been one of the standards in the Haṛappan world, at least as far as town planning and architecture are concerned.

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[26] Kenoyer 1998: 64.

[27] Mackay 1938: 10.

[28] Ibid.

[29] Rao 1979: 1: 123.

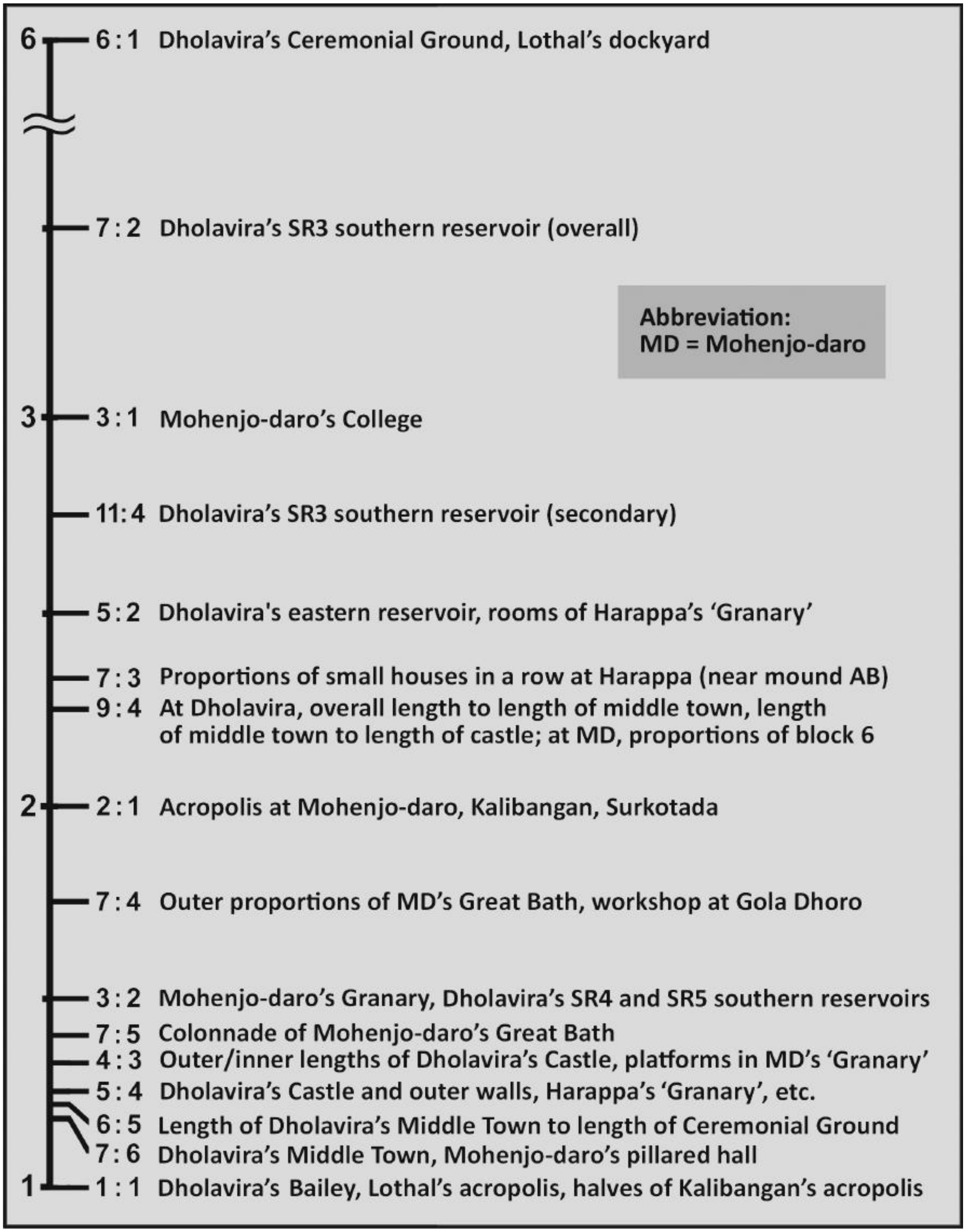

fig. 9.6: A sampling of ratios found at a few Haṛappan sites (on a linear scale), generally with a high degree of precision

Table 9.4: Dimensions at Various Haṛappan Sites Precisely Expressed as Integral Multiples of D = 1.9 m. (The margin of error is included only if the published dimensions are judged precise enough)

Haṛappan Site	*Structure*	*Dimensions (metres)*	*In Terms of D = 1.9 m*	*Margin of Error (%)*
Moheṅjo-dāṛo	Building in HR area	18.9 x 15.2	**10 x 8**	0.7, 0.2
	"College"	70.3 (length)	**37**	0.2
	"Block 6"	56.4	**30**	1%
	"Pillared Hall"	23 x 27	**14 x 12**	—
	"First Street"[30]	7.6 (width)	**4**	0.2
Haṛappā	"Granary"	51.2 x 40.8	**27**	0.2
	12 rooms of granary	15.2 (length)	**8**	0.2
	14 houses (mound AB)	17.06 (length)	**9**	0.4
Dholāvīra	2 stone columns (castle)[31]	3.8 (apart)	**2**	0.0
	Middle town's major street[32]	5.75 (width)	**3**	0.7
	Reservoir SR1[33]	30.35	**16**	0.2
	Reservoir SR3, primary (width)[34]	9.45	**5**	0.5
	Reservoir SR3, secondary (width)[35]	5.65	**3**	0.9
	Reservoir SR4[36]	11.40 (max. length)	**6**	—
Chanhu-dāṛo	Street[37]	5.68 (width)	**3**	0.6
Lothal	Dockyard	216.6 x 36.6	**114 x 19**	—

Dholāvīra's Dhanus and Aṅgula

A unit does not exist singly: it is always part of a system. D = 1.9 m is a large unit and must have had many sub-units. In an attempt to figure them out, let us turn to divisions on the three known Haṛappan scales: those of Moheṅjo-dāṛo (6.7056 mm), Haṛappā

[30] Possehl 2003: 101.

[31] Lal 1998: 44.

[32] Ibid.

[33] Danino 2010b.

[34] Ibid.

[35] Ibid.

[36] Ibid.

[37] Chakrabarti 2006: 154.

(9.34 mm),[38] and Lothal (1.77 mm). The last is evidenced on an ivory scale found at Lothal, which has 27 graduations covering 46 mm. (Both S.R. Rao[39] and V.B. Mainkar erred in dividing 46 mm by 27, when the length must of course be divided by the 26 divisions formed by the 27 graduations.)

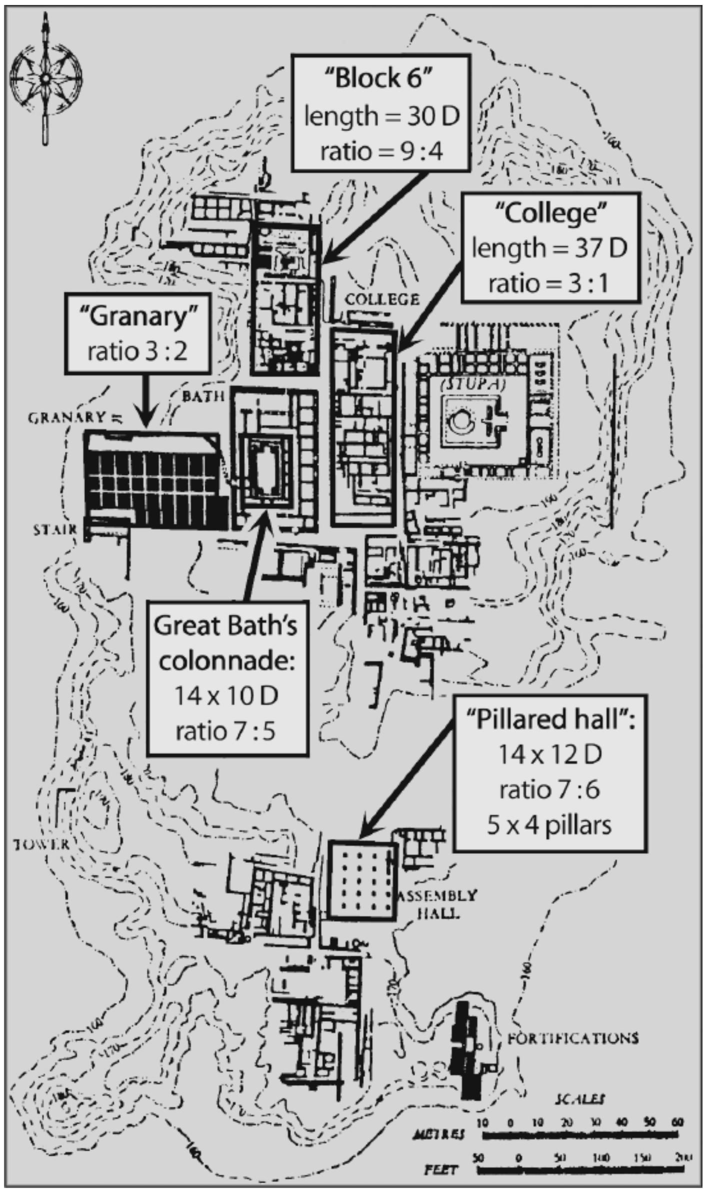

fig. 9.7: Moheṅjo-dāṛo's acropolis: a few ratios and dimensions expressed in terms of Dholāvīra's unit D = 1.9 m

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[38] Mainkar 1984: 146.

[39] Rao 1979: 2, 626.

Dividing D by the first two units yields no clear result. Dividing it by the Lothal unit (1904 by 1.77), we get 1075.7, or, with an approximation of 0.4 %, 1080. This last number can be written 108 x 10. In other words, D can be expressed as 108 times 1.77 cm.

Let us pursue this line of inquiry: what is so special about 1.77 cm? First, let us remember that the values of the traditional digit in the ancient world, be it in Egypt, Mesopotamia, China, Greece, Japan or the Roman Empire, fluctuated between 1.6 and 1.9 cm.[40] Ten times the Lothal unit falls in that range. Then, *Arthaśāstra* defines a digit (*aṅgula* in Sanskrit) as eight widths of barley grain (2.20.6) or "the maximum width of the middle part of the middle finger of a middling man" (2.20.7).[41] Some eight centuries later, Varāhamihira's *Bṛhat Saṁhitā* (LVIII.2) repeats the first definition; that is the "standard" *aṅgula* of classical India (there are indeed variations in later or regional traditions of iconometry, but they need not detain us here). Most scholars from J.F. Fleet down took the *aṅgula* to be "roughly equating . . . $^{3}/_{4}$th of an inch",[42] that is, 1.9 cm. K.S. Shukla,[43] Ajay Mitra Shastri[44] or A.K. Bag,[45] to quote just a few, endorsed this approximate value. In contrast, the metrologist V.B. Mainkar[46] traced the "development of length and area measures in India" and narrowed the value of the *aṅgula* to 17.78 mm. He was probably the first to suggest that ten times the Lothal unit, i.e. 1.77 cm, was almost identical to the traditional *aṅgula*.

Moreover, a crude terracotta scale from Kālibaṅgan was submitted to careful scrutiny by the late R. Balasubramaniam, who established that it is based on a unit of 1.75 cm.[47] This is almost the same as the Lothal unit of 1.77 cm.

Let us average the two and call 1.76 cm "A" for *aṅgula*; we then have the following relation: **D = 108 A**. This is an arresting result, since the concept of "108 *aṅgula*s" is well attested in classical India. For instance, one of the systems of units described in Kauṭilya's *Arthaśāstra* (2.20.19) fits very well in the Dholavirian scheme: "108 *aṅgula*s

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[40] Rottländer 1983: 205.

[41] Kangle 1986: 138.

[42] Chattopadhyaya 1986: 231.

[43] Shukla 1976: 19.

[44] Shastri 1996: 327.

[45] Bag 1997: 667.

[46] Mainkar 1984: 147.

[47] Balasubramaniam and Joshi 2008: 588-89.

make a *dhanus* (meaning a bow), a measure [used] for roads and city walls".[48] "City walls" are precisely the context in which our unit D was used at Dholāvīra and elsewhere. We can now propose that "D" also stands for *dhanus*.

The Haṛappan brick provides us with a degree of confirmation of the Lothal *aṅgula*. In the Mature phase (and occasionally in the Early phase), most bricks follow ratios of 1 : 2 : 4 in terms of height–width–length; among several different sizes in this ratio, one dominates by far: 7 x 14 x 28 cm, measured and averaged over numerous samples (as mentioned by Kenoyer[49] and by Rottländer quoting Jansen[50]); the first dimension, 7 cm, is almost exactly 4 Lothal *aṅgula*s (the difference being just 0.5 mm or 0.7 %). So the humble brick's dimensions can be elegantly expressed as 4 x 8 x 16 A.

Between the *aṅgula* and the *dhanus*, there must have been several important sub-units, and elsewhere[51] I attempted to work out a few of them; preliminary findings are that units of 4, 8, 10, 15, 16, 27 and 36 *aṅgula*s were probably in use in Haṛappan times. However, this requires confirmation through more systematic studies.

Continuity of the Dholāvīra Scheme of Ratios and Units

The scheme of ratio and units found at Dholāvīra finds further echoes in historical times. *Arthaśāstra* apart, "many [early texts] concentrate on the description of an image of 108 *aṅgula*s in length".[52] The origin of the concept behind the sacred number 108 is probably multiple. It could be simply based on the human body: 108 *aṅgula*s (1.9 m) is the height of a tall man, as specifically mentioned by Varāhamihira in his *Bṛhat Saṁhitā* (68.105).[53] From a different perspective, simple but compelling astronomical considerations behind 108 have been demonstrated by Subhash Kak.[54]

Dholāvīra's ratios must have been perceived as specially auspicious, otherwise every enclosure might as well have been square. Some of those ratios are still in use in various traditions of Vāstu-Śilpa. In the sixth century CE, for instance, Varāhamihira wrote in his *Bṛhat Saṁhitā* (53.4-5):

48 Kangle 1986: 139.

49 Kenoyer 1998: 57.

50 Rottländer 1983: 202.

51 Danino 2008: 66-79.

52 Nardi 2006: 260.

53 Bhat 1981: 642.

54 Kak 2000: 101-02, 124.

> The length of a king's palace is greater than the breadth by a quarter. . . . The length of the house of a commander-in-chief exceeds the width by a sixth.[55]

These two ratios, 1 + 1/4 and 1 + 1/6, are identical to 5 : 4 and 7 : 6 — very precisely Dholāvīra's most prominent ratios (see *fig*. 9.2). Such a perfect double match appears to be beyond the realm of coincidence.

A recent work by Mohan Pant and Shuji Funo[56] compared the grid dimensions of building clusters and quarter blocks of three cities: Moheṅjo-dāṛo, Sirkap (Taxila, early historical, *fig*. 9.8), and Thimi (in Kathmandu Valley, a contemporary town of historical origins). Carefully superimposing grids on published plans of all three cities (their own in the case of Thimi), the authors found that block dimensions measure 9.6 m, 19.2 m (= 9.6 m x 2), or multiples of such dimensions. This, they argue, evokes the *Arthaśāstra*'s unit called *rajju*, equal to 10 *daṇḍa*s. As regards the *daṇḍa*, which has four possible traditional values, the authors chose that of 108 *aṅgula*s as prescribed in

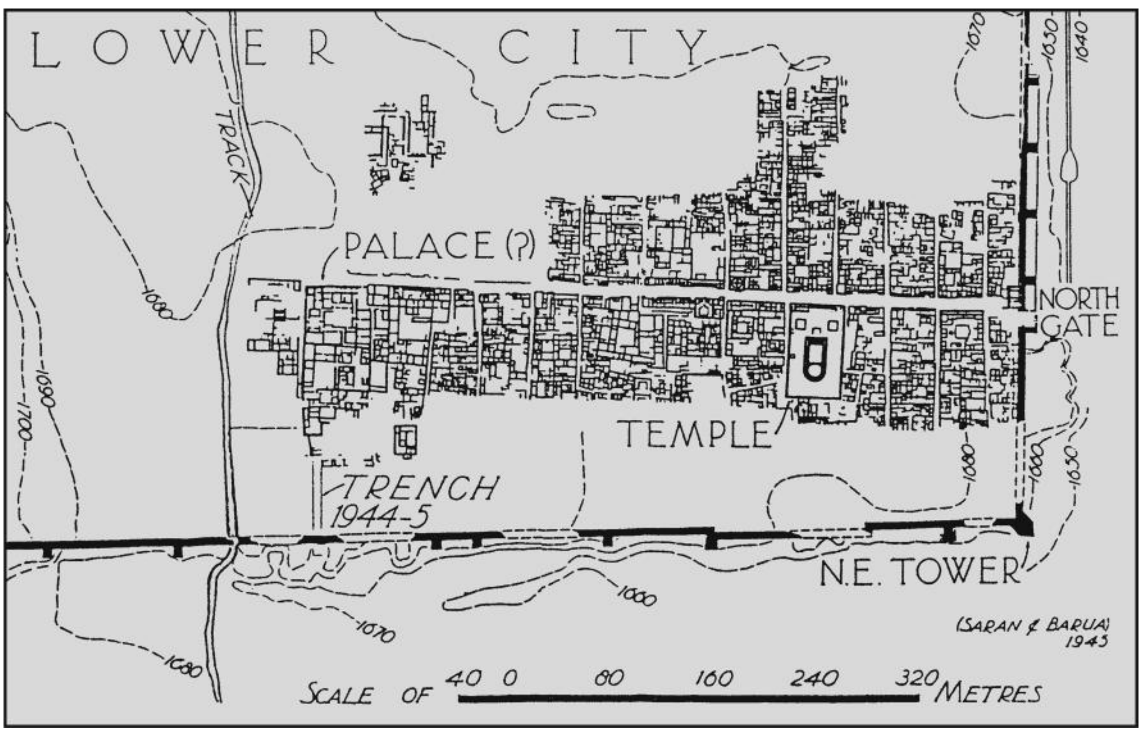

fig. 9.8: Plan of Sirkap, one of Taxila's mounds. The blocks of houses are separated by regularly spaced streets, 38.4 m apart (= 1.92 x 20)

[55] Bhat 1981: 451-52

[56] Pant and Funo 2005: 51-59.

Arthaśāstra (2.20.18-19); it is the same passage which I quoted earlier to define the *dhanus*, and the *daṇḍa* is mentioned in it as another name of the *dhanus*: for our purposes, the two terms are identical.

Pant's and Funo's unit of 1.92 m differs from mine of 1.9 m by just 1 %; in both cases, the unit was equated 108 *aṅgula*s. Their work thus lends support to my suggestion that such concepts survived the collapse of Haṛappan urbanism and re-emerged in Kauṭilya's canons of urbanism. Is this so surprising, when we already know that the Haṛappans' weight system, metallurgical, agricultural and craft techniques did live on, apart from numerous religious symbols and practices?[57]

We get further confirmation of such continuity from a case study of the Delhi Iron Pillar (Qutub Minar complex) by R. Balasubramaniam,[58] who applied to it the Haṛappan *dhanus* and *aṅgula* I had proposed and found they expressed the pillar's dimensions with unexpected harmony (*fig*. 9.9): its total length of 7.67 m, for instance, is precisely 4 D; its diameter, 36 *aṅgula*s at the bottom, shrinks to 24 *aṅgula*s at ground level, finally to taper off at 12 *aṅgula*s at the very top. If this were not enough, the ratio between the pillar's entire length (7.67 m) and the portion above the ground (6.12 m) is 5 : 4, verified to 0.2 % — again, Dholāvīra's master ratio. This bears out once again that Haṛappan ratios and linear units survived the collapse of the Indus cities and passed to those of the Ganges Valley. Balasubramaniam applied the same units with excellent results to engineered caves of the Mauryan period[59] and to the Taj Mahal complex,[60] opening a new line of inquiry in classical Indian metrology.

Haṛappan and Classical Concepts

On a cultural level, the presence of carefully proportioned fortifications as at Dholāvīra might be as much a specific cultural trait as pyramids are to Egypt or ziggurats to Mesopotamia. Here, instead of erecting colossal buildings, enormous energy was spent on defining spaces: the space of the rulers and administrators (the acropolis) and the spaces for other classes of citizens. Demarcating was a vital need not for defence, but for self-definition: fortifications probably stood for authority and segregation, as Piotr A. Eltsov has recently argued too.[61]

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[57] Danino 2003: 21-32.

[58] Balasubramaniam 2008: 766-70.

[59] Balasubramaniam 2009b.

[60] Balasubramaniam 2009a.

[61] Eltsov 2008.

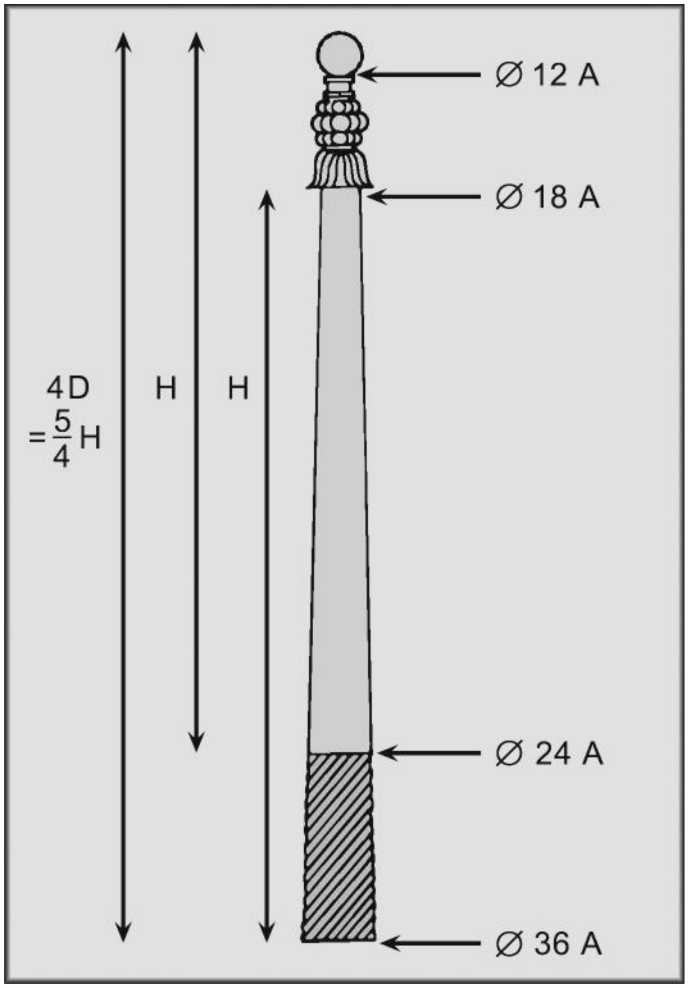

fig. 9.9: A sketch of the Delhi Iron Pillar with the main dimensions expressed in terms of D = Dholāvīra's *dhanus* (1.9 m) and A = Dholāvīra's *aṅgula* (1.76 cm)

But there may also be deeper motives at work: ratios and units apart, we can discern a few important principles underlying Dholāvīra's fascinating harmony, in an almost Pythagorean sense of the term. More work and data are needed to bring out those principles securely, but I proposed elsewhere[62] that the Vedic principle of *addition of a unit* is at work here: 5 : 4 should be read as "one unit plus one fourth", and the key ratio of 9 : 4, for instance, is nothing but 5 : 4 plus one unit. This addition to the unit of a fraction of itself can also be seen as a process of expansion, of auspicious increase

[62] Danino 2008.

symbolizing or inviting prosperity. Thus *Mānasāra*, a treatise of Hindu architecture, applies this process when it specifies (35.18-20) that

> the length of the mansion [to be built] should be ascertained by commencing with its breadth, or increasing it by one-fourth, one-half, three-fourth, or making it twice, or greater than twice by one-fourth, one-half or three-fourths, or making it three times.[63]

The outcome is a series of ratios: 5 : 4, 3 : 2, 7 : 4, 2 : 1, 9 : 4, 5 : 2, 11 : 4, 3 : 1. Since we found all these ratios at Dholāvīra or other Haṛappan settlements, it is tempting to assume that the concept behind such auspicious ratios was the same in Haṛappan times.

Also found at Dholāvīra is another Vedic principle, that of *recursion* or repetition of a motif.[64] Thus the "castle" and the overall city share the same ratio (5 : 4), and 9 : 4 defines the expansion from the length of the "castle" to that of the middle town, and again to that of the lower town.

The thread connecting those principles was anticipated by astrophysicist J. McKim Malville, who saw in Dholāvīra's features "the apparent intent . . . to interweave, by means of geometry, the microcosm and the macrocosm".[65] To the ancient mind, the concept of sacred space was inseparable from the practice of town planning and architecture. Dilip Chakrabarti echoes this in his recent observation:

> The ideals of ancient Indian town planning seem to run deep through the concepts embedded in the Haṛappan cities like Moheṅjo-dāṛo and Dholāvīra.[66]

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63 Acharya 1994: 374.

64 Kak 2009.

65 Malville 2000: 3.

66 Chakrabarti 2006: 166.

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