

UNITS OF MEASUREMENTS IN MEDIEVAL INDIA AND THEIR MODERN EQUIVALENTS*

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The units of length, mass and time, as considered in scientific contribution of Bhoja, will be explored in this paper.

UNITS OF LENGTH

While initiating the process to test the ground for the suitability of building (a city) Bhoja [1, 8.67] states:

Karapramāṇam kurvīta khātam tadbhūmimadhyagam, i.e. one should dig a dug of the dimension of one *kara* in the middle of the ground.

He then tends to standardize the magnitude of a *kara* as follows [1, 9.4-5]:

Renvaṣṭakena vālāgram.....

i.e. 8 <i>reṇus</i>	= 1 <i>vālāgra</i> ,
8 <i>vālāgras</i>	= 1 <i>likṣā</i> ,
8 <i>likṣās</i>	= 1 <i>yūkā</i> ,
8 <i>yūkās</i>	= 1 <i>yavamadhya</i> ,
8, 7 or 6 <i>yavamadhyas</i>	= 1 <i>aṅgula</i> ,
24 <i>aṅgulas</i>	= 1 <i>kara</i> .

According to this, 4096 *reṇus* make a *yavamadhya*. Consequently, the measurement of a *kara* can be described as follows:

(a) 1 <i>prāśaya</i>	= 24 <i>jyesthaṅgulas</i>
	= 192 <i>yavamadhyas</i> = 4096 × 192 <i>reṇus</i>
	= 786432 <i>reṇus</i>

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$$\begin{aligned} \text{(b) } 1 \text{ sādharāṇa} &= 24 \text{ madhyāṅgulas} \\ &= 168 \text{ yavamadhyas} \\ &= 685128 \text{ reṇus} \end{aligned}$$

$$\begin{aligned} \text{(c) } 1 \text{ śaya} &= 24 \text{ kaniṣṭhāṅgulas} \\ &= 144 \text{ yavamadhyas} \\ &= 589824 \text{ reṇus} \end{aligned}$$

The lengths and dimensions of villages, towns, cities, palaces, houses, moats, lanes, assembly halls, small and big gardens and regional separating lines were measured in terms of *prāśaya*.

It is to be remarked that the length of *yojana* (*krośa*, and *gavyūti*) which is conceived to be the unit of the dimension of earth and that of the continents and the length of highways, was also fixed according to *prāśaya*.

Dugs, saws, heaps of grains etc., elevation of surfaces, base-roots of the walls and columns etc. and the water ponds below the ground level, flags, hilly houses, internal dimension of the holes, lanes inside the plantations were measured in terms of *sādharāṇa*.

Dimensions of weapons, sticks for bows, vehicles, sleeping places, seats, wells, ponds, elephants, horses, (heights and partial dimensions of) human body, wheels for uplifting water from wells, sugarcane-crushing machines and the instruments of harvesting and carpentry, boats, instruments of ironsmiths, the musical instrument (*vīṇa*) and the instruments of weavers were measured in terms of *śaya*.

If we take normally big *kara* to be of 45 centimeters length, then the above units suggest the following facts:

$$\begin{aligned} \text{(a) } 1 \text{ prāśaya} &= 45 \text{ cms} = 450 \text{ mms} \\ &= 786432 \text{ reṇus} \end{aligned}$$

$$\text{(b) A reṇu, which was considered to be the least count for linear measurements, is equivalent to .00057 mms} = .000022 \text{ inches approximately.}$$

It is surprising how a length of order 1/2000 mms was measured before the invention of the instruments like screw gauge or vernier callipers. Also one should not have a doubt upon their practicability since they have been employed in [1, 12.31-32] as follows:

Vālāgratulyam sandhīnām pramāṇam paricakṣate
tādardhamanusandhīnām pramāṇam samudiritam

and in forming *Samabhujasadasrakund*, *Padmakund* etc. [5, 45-46].

If we take up the longer measurements we notice the following facts [1, 9.45-47]:

96 <i>aṅgulas</i>	= 1 <i>cap</i> or <i>dhanu</i>
1000 <i>dhanus</i>	= 1 <i>krośa</i>
2 <i>krośas</i>	= 1 <i>gavyūti</i>
4 <i>gavyūtis</i>	= 1 <i>yojana</i> .

This shows that 1 *krośa* = 1000 *dhanus*
 = 4000 *prāśayas*
 = 4000 × 24 *jyeṣṭhāṅgulas*
 = 4000 × 24 × 15/8 centimeters

i.e. 1 *krośa* = 1.80 kilometers.

This clearly shows that the *krośa* corresponds to a mile known in the present society which is equal to 1.6 kilometers, *gavyūti* corresponds to *krośa* of the present time and thus the conception that 'a *yojana* consists of 4 *krośās*' is consistent.

The facts below are worthnoticing--

(a) *Yavamadhya* is not a well-defined measure since all *yavas* are not equal. This raises a question 'which of the *yavas* should be taken as standard?' Although the present scientific system is also not free from this limitation: A meter, which is defined to be one ten-millionth of the length of a quadrant of the meridian, is kept at Paris in its standard form and nearly corresponds to 39.37079 English inches. One can ask the following:

- (i) The length of a meridian may slightly differ in different directions and also it may vary slightly with the time.
- (ii) That it is one ten-millionth of the length of a quadrant of a meridian is hypothetical.
- (iii) Since no two things in the universe are of equal length, it is doubtful whether a certain meter-scale is just equal to the meter kept at Paris; yet the meter-scale is not subject to much variation like the *kara* because *kara* is totally subjective.

(b) Unlike the present scientific measures the intermediary scales in small measurements are defined in terms of arithmetic ratios (although they are defined in geometric ratios in case of scales of very minute and considerably long measurements like *vālāgras* etc. and *krośa* etc.):

*Syādekamaṅgulam mātrā kalā proktāṅguladvayam
Parva trīṅyaṅgulānyāhuḥetc. [1, 9.40-45]*

Consequently the measurement *aṅgula* is frequently applicable while the intermediary ones have rare applicability. However, we find the use of the following intermediary units:

Muṣṭi and *vitasti* have been used in [2, *Śastrayuktiḥ*, verse 478, 486; and *Caṣa-koddeśah*, verse 89 etc.] as:

*‘Dīrghasya mānam nirdiṣṭam bhānu-dīnnavamuṣṭibhiḥ
Valayasya hi nirdiṣṭam tāvatibhirvitastibhiḥ’*

and *‘Swamuṣṭisammitam ratnam caturvarṅgih samanvitam’*

Muṣṭi and *aṅgula* have extensively been used in fixing the dimension of a sword in [2, *Śastrayuktiḥ*].

(c) In [1, Chapter 9], the definitions up to *daṇḍa* are given in terms of *aṅgula* and no measurement except *aṅgula* is employed to define its own successor while *nalva* and *krośa* are defined in terms of *dhanu* without notifying that it is just the *cāpa* defined before 2 steps. As a result one may get lost in tending to interconnect *daṇḍa* and *nalva* by some simple ratio. It is to be noted here that in [2, *Hayadhāvanavidhi*] *dhanu* has been fixed in a different way. According to this, 24 *hastās*=1 *dhanu* while according to [1, 9.45] a *cāpa* or *dhanu* is equal to 96 *aṅgulas*=4 *karās*.

Thus, although we find that the linear measurements seem to be subjective, yet there is expected some standard unit; may be, in the King’s Court, by which the least count *reṇu* (=1/4096 *yavamadhya*) was fixed.

Of course, in the literature of Bhoja and in other indological works the linear measurements are of two types:

(1) *General Measurements*

These were performed in way to solve public or social problems. For example, *yojana* was fixed according to standard *kara* whose length must have been fixed up by the King’s Court and certainly it must have been free from any subjectivity. Distances would have been measured according to this standard unit [1, 9.32-33]. All the linear measurements except the subjective ones were measured by this standard unit otherwise there would not have been a classification of *hastas* as in [1, 9th Chapter]. Hence we can infer that the standard *prāśaya*, *sādhāraṇa* and *śaya* would have been standardized by the administration.

Thus we can see that the linear measurements given in [1, Chapter 9] belong to this category.

(2) *The second, which was totally subjective, was employed in the following two ways :*

(a) *Measurement subjected to king's hand:* While constructing different parts of the palaces and while taking linear measurements of the belongings of the king, the linear dimensions were measured by the unit *rājahasta* which was according to the actual length of the king's hand [2, *Nītiyuktiḥ*, verses 148, 169; *Vāstuyuktiḥ*, verses 255, 256, 259, 274 and *Āsanayuktiḥ* verses 353 etc.]. In this measurement seven units have been used [2, *Nītiyuktiḥ*, verse 148-151]:

10 times of the length of the king's hand	= 1 <i>Rājahasta</i>
10 <i>rājahastas</i>	= 1 <i>rājachatra</i>
10 <i>rājachatras</i>	= 1 <i>rājakāṇḍa</i>
10 <i>rājakāṇḍas</i>	= 1 <i>rājapurūṣa</i>
10 <i>rājapurūṣas</i>	= 1 <i>rājapradhāni</i>
10 <i>rājapradhānis</i>	= 1 <i>rājakṣetra</i> .

These measurements have been used throughout [2].

(b) *Measurement subjected to an individual from among the general public:* It has been employed in [2, *Vāstuyuktiḥ*, verse 327] as follows:

Swānihastapramāṇena jyeṣṭhapatnīsutena vā |
Gṛhādyanarasamsthānam māpayedabhiṭo naraḥ ||

Its subjectivity to an individual is further confirmed by the following [*ibid*, verse 335 and 344]:

'Evam grham samācaryya grhasthaḥ śubhamicchati' and
'Tadvicārya grham kṛtvā grhasthaḥ sakhamāśnute'.

Hasta, without distinction, has also been used in [2, Chapter I, verse 485; Chapter II, verse 10, 11 etc.].

It should be remarked here carefully that the things, which were not personal and used by the general public, were measured by the unit *rājahasta*. For example, the dimension of a boat has been given in [2, *Naūyānayuktiḥ*] in *rājahasta* unit as follows:

'Rājahastamitāyāmā tatpādapariṇāhīni'
'Rājahastadvayāyāmā aṣṭāśāpariṇāhīni'
and *'Rājahastaikaikavṛddhyā naukānāmāni vai daśa.'*

While mentioning the dimension of *Padmarāga*, Bhoja [2, *Vajrayuktiḥ*] has a description of the dimension of *Badarīphala* and *Dhātrīphala* etc. As earlier, these

fruits are not necessarily of unique dimensions. This phenomenon again suggests the standardization of the measurements of these fruits also by the administration.

One more definition of a *hasta* is found in [5, 3-4] as follows:

Take the fifth part of the length of a man standing on his toes on a plane ground and keeping his hands raised exactly upwards, we get the length of a *kara*, say *k*.

Then *aṅgulam* = $k/24$, *yavamadhyam* = $k/192$ etc. This was used by *vaidikās* in *karmakāṇḍa* and is totally subjective of the type 2(b) above.

MEASUREMENTS OF WEIGHTS

Although in [1, 9.1] it is stated that *Mānonmānavibhāgādi-nirṇayaikanibandhanam*, yet there is no mention of the units of weights in [1, Chapter 9]. However, since in his āyurvedic treatise [3], he mentions *karṣa droṇa* etc., it seems that the measures like *karṣārḍha*, *karṣa*, *droṇa*, *prastha* etc. considered by the earlier scientists, were well accepted and employed in the scientific activities [3.96, 106, 107, 118]. These can be seen in a systematic way in [6, *Kalpasthāna*, Chapter 12]:

6 <i>vaṁśyas</i>	= 1 <i>marīci</i>
6 <i>marīcis</i>	= 1 <i>sarṣapa</i>
6 <i>sarṣapas</i>	= 1 <i>yava</i>
3 <i>yavas</i>	= 1 <i>raktikā</i>
10 <i>raktikās</i>	= 1 <i>masa</i>
4 <i>masas</i>	= 1 <i>sāṇa</i> [3; p. 34, 36]
2 <i>sāṇas</i> (<i>niṣka</i>)	= 1 <i>kola</i> [ibid] (<i>kola</i> is also mentioned on p. 50, 99, 151)
2 <i>kolas</i>	= 1 <i>karṣa</i> [3; p. 61, 86, 91, 96, 99, 134, 153, 156]
2 <i>karṣas</i>	= 1 <i>śukti</i>
2 <i>śuktīs</i>	= 1 <i>pala</i> [3; p. 47, 85, 86, 99, 105, 107, 129, 134, 142, 149, 150, 151, 156]
2 <i>palas</i>	= 1 <i>prasṛti</i>
2 <i>prasṛtis</i>	= 1 <i>añjali</i> or <i>kuḍava</i>
2 <i>añjalis</i>	= 1 <i>śarāva</i>
2 <i>śarāvas</i>	= 1 <i>prastha</i> [3; p. 5, 105, 140, 142]
4 <i>prasthas</i>	= 1 <i>āḍhaka</i> [3; p. 49, 142]
4 <i>āḍhakas</i>	= 1 <i>droṇa</i>
2 <i>droṇas</i>	= 1 <i>sūrpa</i>
2 <i>sūrpas</i>	= 1 <i>droṇī</i> or <i>vāh</i>
4 <i>droṇīs</i>	= 1 <i>khāri</i> = 4096 <i>pala</i>
2000 <i>palas</i>	= 1 <i>bhāra</i>

These very measurements are found in [7, Chapter 8] with few variations in the lighter ones:

(A small particle seen in the rays of sunlight= 1 trasareṇu) $1 \text{ trasareṇu} = 1/8 \text{ likṣā} = 1/24 \text{ rājasarṣapa} = 1/72 \text{ gaurasarṣapa} = 1/432 \text{ medium yava} = 1/1296 \text{ raktikā} = 1/6480 \text{ māṣa}$.

According to [3] scientists in the period of Bhoja seem to follow Caraka. Thus the present *māṣa*, *tolā* (*kola* according to Caraka) *chatāṅka* and seer have the following relations:

1 gram = 1.026 *māṣa* approximately = 6648.48 *vaṁśyas* approx.
 and so 1 *vaṁśya* = .00015 grams approximately,
 30 grams = 31 *māṣas* approximately,
 500 grams = 43 *tolās* approximately.
 1 kilogram = 1 seer and 1 *chatāṅka* approximately.

This gives the following equivalents:

1 *raktikā* = 121 miligrams approximately,
 and 1 *tolā* = 11 grams and 664 miligrams approximately.

Also we get

1 *māṣa* = .00227 pounds

The lower order measurements of [6] like *vaṁśya*, *marici sarṣapa*, *yava* and *raktikā* are hardly seen in Bhoja [1]-[4]. On the other hand, *niṣka*, which finds a mention in [7], is used as a lower order measurement [3; p. 8, 107, 128, 129, 135, 141] and is equal to a *sāṇa* of the Caraka system by the following observations:

According to Caraka cited above, 16 *sāṇas* = 1 *pala* and according to '*Palam ṣoḍaśaniṣkaparimitam* [3; p. 34]

16 *niṣkas* = 1 *pala*.

The statement '*Guñjābhīḥ saptabhirmāṣam*' gives perhaps, the smallest measurement of weights mentioned in [1]-[4] which is *guñja*. It is 1/7th part of a *māṣa* and consequently equals to 0.14 gms. approximately. In the case of precious stones it is 1/5th part of a *māṣaka* [2, *Muktādīmūlyayuktiḥ*].

Before concluding this section we have the following remarks:

- (a) As is clear from the above, a *kola* (*tolā* in present society) is equivalent to 2 *niṣkas*. But the commentary '*Tolamāneneti triniṣkamānenetyarthaḥ*' [3; p. 48] tells us that *tolaka* is equivalent to 3 *niṣkas*. However, footnote No. 1 [3; p. 48] also does not solve the problem as it only tells that according to the author of [3] 1 *pala* is equivalent to 4 *tolakas* while the previous workers conceived it to be equivalent to 8 *tolakas*.
- (b) *Prasṛti* and *añjali*, which have been mentioned as measurements of weights, seem to be volumetric measures only. However, in the case of some particular medicines they must have been accepted for determining the amount

of the medicine for a particular person. In that case it is a totally subjective measurement of the volume of the particular medicine. Somehow if the subjectivity of *marīci sarṣapa*, *yava* etc. can be removed by standardizing it in the King's Court (as in the case of linear measures of section 1), it can be removed in the case of *prasṭi* and *añjali* as well. In that case these will be some well defined measures of weight fixed by the administration and the question of their being volumetric does not arise. Rejecting this convention we may get absurd results:

1 *prasṭi* of mercury weighs 13.6 times than 1 *prasṭi* of water.

MEASUREMENTS OF TIME

As found in [1, 9.51]

15 <i>nimeṣas</i>	=	1 <i>kāṣṭhā</i>
30 <i>kāṣṭhās</i>	=	1 <i>kalā</i>
30 <i>kalās</i>	=	1 <i>muhūrta</i>
30 <i>muhūrtas</i>	=	1 <i>aharṇiśa</i> = 24 hours.

The duration of time between two consequent sunrises is 30 *muhūrtas* which is consistent with [8, *Gaṇitādhyāya*, *Madhyamādhikāra* verses 16-18] where *muhūrta* is accepted to be the 1/30th part of one *ahorātra*. Thus a *muhūrta* is equivalent to 48 minutes. Consequently

1 <i>kalā</i>	=	1 minute and 36 seconds,
1 <i>kāṣṭhā</i>	=	3.20 seconds,
		and the least count <i>nimeṣa</i> = 16/75 = 0.2133 seconds.

It is worth mentioning here that in [1] we get only one measurement of time which may be accepted to be *sthūla gaṇanā* or gross measurement of time according to [8] and [9]. In [9] the unit for minute (*sūkṣma*) measurement is *Truṭi* which is 1/3240000 second. It is to be remarked here that this measurement has been employed in 'Tāvadetyātmabhūratmamānena truṭyanehasā [10.13]. The unit for gross measurement i.e. *sthūla kālā* is however an *asu* (or a *prāṇa* which is taken to be 4 seconds [9, *Madhyamādhikāra*, page 7]).

Thus

1 <i>prāṇa</i>	=	1/6 <i>pala</i>	=	1/15 minutes	=	10 <i>vipalās</i> ,
		and 60 <i>palās</i>	=	1 <i>daṇḍa</i> (<i>nādi</i> or <i>ghaṭī</i>)	=	24 minutes
		and 60 <i>daṇḍas</i>	=	1 <i>ahorātra</i> ,		

while *truṭi* = 1/60 *reṇu* = 1/(60)² *lava* = 1/(60)³ *likṣaka* = 1/(60)⁴ *prāṇa*.

Hence *nimeṣa* (the unit of time in [1])

$$= 0.2133 \text{ seconds} = 0.0533 \text{ prāṇas} = 691200 \text{ truṭis.}$$

One more fact is to be mentioned here that the *Vāsanā Vārtika* commentary on [8, verses 16-18] has an account of three more concepts on *nimeṣa*. Thus a *nimeṣa* = 4/45 seconds according to some scholars, while it is 1/25th or 2/135th part of a second according to others.

Several considerations on the unit of time have been provided in [8] and it is mentioned that the variation in the length of the unit *nimeṣa* is due to the actual variation of the *nimeṣa* of the eyes in different human bodies:

‘*Nimeṣatāratamyādadoṣaḥ*’ [8, commentary of verses 16-18, p. 51].

Finally, we come on the second factor mentioned in the introduction, viz. the number. [1] tells us the numbers ranging from 1 to 10^{19} . The numbers up to this range were given in *Taittirīya Saṃhitā* [11, 7.2.20] but with slight variation of the terminology: The numbers from 1 to 10^8 , i.e. *nyarbuda* have the same terminology as in [11]. But the bigger ones have different terminologies as is clear from the following table:

Numbers	Terminology in [1]	Terminology in [11]
10^9	<i>vrnda</i>	<i>samudra</i>
10^{10}	<i>kharva</i>	<i>madhya</i>
10^{11}	<i>nikharva</i>	<i>anta</i>
10^{12}	<i>śaṅku</i>	<i>parārdha</i>
10^{13}	<i>padma</i>	<i>uśas</i>
10^{14}	<i>ambu</i>	<i>vyuṣita</i>
10^{15}	<i>madhya</i>	<i>deśyat</i>
10^{16}	<i>antya</i>	<i>udyata</i>
10^{17}	<i>par</i>	<i>udita</i>
10^{18}	<i>apar</i>	<i>suverga</i>
10^{19}	<i>parārdha</i>	<i>loke</i>

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