The linear measurements were in relation to body parts of human. The *angula* measure being the basic unit, was derived from minor units like diameter of Banyan seed, mustard seed, seasmum seed, barley grains etc and in multiples of eight units. Multiples of *angulas* were used in the form of *vitasti*, *hasta*, *aratni*, *danda* and *Rajju*. It appears that the standard scale was a *hasta* long consisting of 2 *aratni* and it was 24 *angula* long. This 24 *angula* scale is called as *gaja*.

The multiples and divisions on the 24 *angula* scale are the same. These are found scales at Shravanabelgola scale near foot of Gommatesvara, Kalkeri, Keladi and the Bhagamandala scales. The length of *angula* in Shravanabelgola scale of AD 981 is 4.00cms. In 11th Century Kalkeri scale it is 3.525cms, in Keladi Scale of AD1672-1697 it is 3.302cms and in Bhagamandala scale of AD1790 it is 3.00Cms. This shows that from period II to IV there is gradual reduction in the standard length of an *angula* from 4.00cms to 3.00cms.

Thus over a period of nearly 800 years the divisions and the pattern of scale have remained the same, but the *angula* length has gradually diminished in size.

The next common unit was *genu* (distance between out stretched thumb and fore finger). Most of the scales found in Karnataka are in multiples of this unit. The length of a *genu* (span) was nearly equal to 23.00 cms. The study has shown that 139 scales with different names and 35 scales with different measures existed in the study period. The *gale* i.e. measuring pole was in multiples of the standard *gaja* in a region. There are scales named after individuals who held important positions in the administration, titles of the regional leaders, village name, deity name, sub division and division’s name. There were scales called as tank measuring scale, crop scale etc.

The study has brought to light evidence of a dozen new archaeological scales. The scale length indicated on monuments need not be the full length of measuring scale used in fields. Multiples of these standard units were used.

The occurrence of different scales in Karnataka throws out an interesting fact. The pole named after Ganga – *gangana gale* and the land measure *gangana mattar* do not occur in the core region of Ganga rule. It is found in the fringe area of their rule in Nolambavadi region during 10-12th century (period II & III).
**Vishnuvardhana gale** named after Hoysala king is found at Dharwad region and not in the core area around their capital Belur in Hassan district.

The scale marks indicating the ends of measurement are simple. They are mere straight lines in period IV. In the period I, II and III they were more complex with circles having perpendicular lines, Trident shapes, Damaru Shaped blocks, Plus shape and T marks laid horizontally.

**Manikesvarada kolu** and **Manikesvarada mattar** is found to have been used in large area of north Karnataka which comprised of the districts of Bijapur, Bagilukote, Raichur and Gulbarga. The geographical area occupied by these districts is nearly 20% of the study area. There are inscriptional evidences to show that the same scales are being used for more than a century, and its use might have had a greater period than suggested by inscriptions, because the general use and its appearance in egpigraphs take some time.

Though few scales were used in wider region, they never transgressed the greater administrative divisions of medieval Karnataka like Banavasi-12,000, Belvola etc. For example it is interesting to note that Kachchaviya gale was used for more than 160 years in the sub divisions of Nagarakhanda -70, Edavatte -70, Sattalige -70, and Binnavuru -12 within the division of Banavasi- 12,000.

The plot of taluks having scales, on map of Karnataka reveal that there are no scales in malnad and coastal region. Intensive settlement and cultivation of fields was there in plain regions. This was one of the reasons for appearance of more scales. The intensive cultivation also led to disputes between different land owners. Use of measuring pole is an indication of introduction of a standard, however local it may be. The isolated village hamlets and geographical conditions where agricultural land was inter spread with forest did not demand accurate measurement. The hilly areas were probably sparsely populated, so that there was no need to have intensive land measurement based on standardized scales. The agricultural land pockets were probably not adjacent to one another. However all these are tentative explanation and needs further probing. The volume measure was very much in vogue in this region.

The introduction of new scales is more during period II (65 % during Kalyana chalukya rule) and then in period III (30 % during Hoysala and Seuna rule). The introduction of greater number of new scales show / indicate that there was rigorous reforms in land measurement and taxation. The knowledge regarding
the revenue assessment and taxation based on land measurement is totally inadequate at present. It is generally believed that the kingdoms of medieval Karnataka did not indicate any such standardized assessments. But it is likely that during the transition period between the end of Rashtrakuta period or the commencement of Kalyana Chalukya rule there was an attempt by the state for assessment based on mattar and its sub units. Perhaps the wide use of the numerical suffix to the administrative divisions was a consequence of such an assessment. Such an assessment might have taken into consideration the varied local situations which might have lead to the emergence of a variety of scales in different localities.

The canonical prescriptions were used in carving images and building temples. The comparison of measurements of the image Gommatesvara to the scale carved below his feet shows that the image is in Sapta tala. Mallitama the great sculptor has supervised many temples in different places, affixed his signature on more than 80 images. He has revealed the scale followed by him on the Sridhara image carved at Javgal in Lakshmi Narayana temple. The image is in Nava tala.

Milestones were erected on important routes. The Krishnaraja haridari stones at distance of 5280 gaja are found in the study period IV.

As per the standard linear scale discussed earlier, standardization was achieved in terms of units, even though the exact length of the units varied from place to place. Area measurement also seems to have undergone similar standardization i.e the units remaining the same the exact area differing. Since the exact length of the unit varied from place to place, scales had to be carved in each locality for a permanent reference. This is how the carved scales in different parts of Karnataka were obtained. The study of area measurement has shown that, the land was classified based on soil fertility and water facility offered to it. The Nivartana / Mattar unit area measure of period I was measured in period II and was found to comprise of large area. The inscription at Gulbarga district show that the earlier 20 mattar (period I ?) was converted into 81 mattars of present value in period II. There is another inscription which indicates that the measuring gale was reduced to quarter of its length and the mattar measured by this scale was later called as kaladi mattar (quarter mattar)
Various scholars have tried to find out the value of *mattar* in present day terms. The unit area of *mattar* has varied from half an acre to nine acres according to different authors.

The study of data in inscriptions with application of mathematical formula has shown that the unit value of *mattar* is different for different lands in a village of period II. There is evidence in period III at Arasikere taluk, which reveal that wet land was measured with small scale (5 *maru*) and dry land with big scale (7 *maru*). This shows that the unit area of wet land and that of dry land was 5 X 5 : 7 X 7, 25 : 49 Approximately 25:50 i.e. 1:2.

Probably the unit area of *Nivartana/mattar* was constant in study period I. But due to refinement in measurement and introduction of numerous scales in different geographical regions the standard value was altered. Also it was the intellectual development of the community in identifying different soil types and its behaviour on supply of water facility.

The Mathematical work *Ganita Sara Sangraha* of Mahaviracharya written in period I, *Vyavahara ganitam* of Rajaditya in period III and *Kshtera Ganita* of Timmarasa in period IV show that the contribution of Karnataka to the development of this science is of great importance. The works follow similar pattern in their proposition and explanation. According to them the sub unit of *mattar* is *kambha/kamma*. The unit area of *kambha* is one measuring pole on either side (*Gale galeya gunise kambha*). The occurrence of a number of scales in Karnataka was observed by Rajaditya and Timmarasa in period III and IV respectively. The study has also documented this fact with inscriptionsal evidence. The unit area of *mattar* need not be a fixed value, because it comprised of a number of *kambha* sub units. The unit area of *kambha* was in turn dependent on scale length, which varied from region to region.

The unit value of *mattar* can be compared with the present day standard acre concept. The Karnataka Land Reforms Act of 1961 introduced the standard acre concept where the standard acre was based on soil type, fertility status and water facility offered. One acre of A class land is equal to 2 acres of B class land and is equal to 4 acres of C class land. (Appendix II)

For the above reason foreign traveler's and administrators found great difficulty in understanding measurement system of India. Francis Buchanan has written in great detail how the area, volume and weight measures varied from
region to region. The linear and area measures were to be common in a particular region, but it was not so in the case of Volume and Weight measurements. Buchanan is of the opinion in Mangalore that these differences have no doubt been introduced in order to confuse the officer of revenue. In Nagara province he finds that though the actual capacity of areca trees in a field was 300 trees in the books of records it was written as 100 only. Francis Buchanan has completely misjudged the Indian system. Here actually only the yield bearing trees were accounted for. Though the actual capacity of a field was known, the count of the dead and non bearing plants were deducted.

_Daya_ was said to be the tax on plantation crop by Lewis B. Rice. _Daya_ is spacing of plantation crops, and on 1000 such _dayas_ the tax _sist_ was fixed. Mathematical analysis of inscriptive data in period IV has shown that _daya_ was $1/1000^{th}$ of the revenue yield from a plantation.

Volume measure was more in abstract form, where the yield was assessed at the time of harvesting by traditional measurement system. The circumference of a heap of grain or the height of _meti_ (stick in the centre of heap) was used for calculation of volume. The tax was some times on grains which were not fully cleaned. The tax was on carrying capacity of cart and also on pulling capacity of the bullocks. The animals were classified as strong and weak.

_Bhaskaracharya_ has given volume calculation based on grain size and shape. The height of a heap of big and spherical grains is $1/10^{th}$ of its circumference and for small grains and angular grains it is $1/11^{th}$ and $1/9^{th}$ of circumference respectively. This method was probably prevalent in Karnataka, also, and the volume measurement units were standardized, however the contents in a standardized units differ depending upon the size of grains. _Rajaditya_ has noticed this difference and has given the count of number of Paddy, Black gram and Green gram grains in a particular unit That is why there is so much variation in unit value from region to region and within a region.

The weight system and the inter conversion among various units was different for different materials. _Mahaviracharya_ the author of _Ganita Sara Sangraha_ in period I gives different table of measurements for gold, silver and other materials. One _Dharana_ of gold was equal to 16 _gunja_ where as in case of silver it was 32 _gunjas_. Gold being costly, smaller weight was valued at higher costs.
Time measurement was a part of their day to day activities. The details of planetary position are given in some inscriptions and literary books. Zodiac pillars and symbols are found in some places. The 12 zodiac pillars at Sringeri Vidyaranya temple is a good example. The shadow measurement and in turn calculation of time appears in all the mathematical works. Though this is an approximate one was used in day to day activities without much problem.

The concept of measurement system among various types i.e linear, area, volume, weight and time was same throughout Karnataka. The same concept is found even in other parts of India. Though the concept is same, the unit lengths are constant, in measurement it varied from region to region. The multiples of conversions were same but the measured length of scales changed. The unit length was fixed on regional considerations and this was accepted. There was no problem in understanding various units and sub units. The kingdom did not interfere in the measurement system, as this was more of standard nature in concept, but in practical implementation had its own unit measurement, and conversions were according to the standard tables.

The most revealing thing is that whether it was linear or volume measurement, it was derived from the basic units of like that of a grain of a region and the span length of an individual which where highly relative which ended up in inevitable differences. The only way to accommodate these differences in the standardization was to base the measurement on units and not on the actual contents within the unit measure or unit volume.