The First Urbanization Period

And The Indus Valley Civilization

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1. Introduction

The First Urbanization Period (c. 3100–1500 BCE) refers to the rise of the earliest complex societies with cities, social hierarchies, and centralized governments. Egypt, Mesopotamia, and the Indus Valley were three of the most prominent civilizations during this time. While they shared many similarities, they also had distinct differences in geography, government, economy, culture, and technology.

The main reason for this development was the *surplus of agricultural production*, which led to population growth, social stratification, and economic specialization. As Gordon Childe writes,

‘’The worst contradictions in the neolithic economy were transcended when the farmers were persuaded or compelled to wring from the soil a surplus above their own domestic requirements, and when this surplus was made available to support new economic classes not directly engaged in producing their own food. The possibility of producing the requisite surplus was inherent in the very nature of the neolithic economy. Its realization, however, required additions to the stock of applied science at the disposal of all barbarians, as well as a modification in social and economic relations. The thousand years or so immediately preceding 3000 B. C. were perhaps more fertile in fruitful inventions and discoveries than any period in human history before the sixteenth century A. D. Its achievements made possible that economic reorganization of society that I term the urban revolution.’’

Egypt was centered around the Nile River, which provided predictable annual floods, fertile soil, and a natural protective barrier (deserts), fostering a long-lasting civilization. Mesopotamia was located between the Tigris and Euphrates Rivers in modern Iraq. The unpredictable flooding and a lack of natural barriers made it prone to invasions and environmental challenges. The Indus Valley was centered around the Indus River (modern Pakistan and northwest India), with well-planned cities that relied on seasonal monsoons and an extensive irrigation network.

There is considerable archaeological evidence of Urban Planning and Architecture during this period. Egypt is characterized by monumental architecture (pyramids, temples) built primarily for religious and funerary purposes. Cities were not dense, with a focus on grand structures.

Mesopotamia is characterized by Ziggurats (massive temple complexes), centers of religious and political life. Cities were densely packed with narrow streets and mud-brick buildings.

The Indus Valley is characterized by highly advanced city planning with grid systems, drainage, and sanitation as in Mohenjo-Daro, Harappa, and Dholavira. The cities had uniform architecture, suggesting strong urban regulation.

The recent discoveries in Rakhigarhi confirm the same pattern. Rakhigarhi is one of the largest and most significant sites of the Indus Valley Civilization, located in present-day Haryana, not very far from Delhi. Dating back to around 2600–1900 BCE, it was a major urban center with well-planned streets, drainage systems, and multi-room houses. Excavations have revealed pottery, jewelry, tools, and evidence of early writing. DNA studies from Rakhigarhi have provided insights into the genetic makeup of the Harappan people. The site is crucial for understanding the civilization's social, economic, and cultural aspects, shedding light on its connections with other ancient cultures.

While Egypt and Mesopotamia had writing systems (the Hieroglyphics and Cuneiform), the Indus Valley script, found on seals and pottery, is still undeciphered.

2. Key Sectors of the Indus Valley Economy

Agriculture

Agriculture was the foundation of the Indus economy, sustained by river irrigation (Indus, Ghaggar-Hakra, and Sarasvati Rivers). The fertile land allowed the growth of surplus crops, fuelling urbanization and trade.

Wheat, barley, millet, and possibly rice (found in later Indus sites), legumes (lentils, peas, sesame), cash crops like cotton (the Indus Valley was one of the earliest known cotton industries in the world), fruits (dates, melons), and spices (mustard and turmeric) were cultivated. Evidence from Kalibangan suggests the use of wooden plows. Canals and wells were used for Irrigation, but there is no evidence of large-scale irrigation like in Mesopotamia.

Cattle, buffalo, sheep, and goats were raised for dairy, meat, and labor. Camels and donkeys were used for transportation. Elephants may also have been domesticated for trade and construction work.

A stable agricultural base supported specialized workers, traders, and artisans. The production of cotton textiles contributed to long-distance trade with Mesopotamia.

Industry and Craft Production

The Indus people were skilled artisans, producing a variety of goods for domestic use and export. The major industries were pottery (mass-produced painted and plain pottery), metalwork (copper, bronze, and silver tools but not iron), jewelry (bead-making with carnelian, agate, lapis lazuli, gold), textiles (cotton weaving), standardized fired brick-making for urban planning, and seals and writing for identification and trade documentation.

Chanhudaro is famous for bead-making and metalwork, Lothal for shipbuilding, dockyards and jewelry workshops, and Mohenjo-Daro and Harappa for large-scale pottery and brick-making industries.

The presence of high-quality crafts and standardized goods suggests state or guild-level economic planning. Indus artisans exported their products as far as Mesopotamia, Central Asia, and the Persian Gulf.

Clearly, the Indus Valley Civilization was one of the earliest major trade economies. Their advanced standardization and long-distance trade connections made them a major part of the Bronze Age economy. This would not have been possible without a corresponding degree of advancements in science and technology.

3. **The Origins of Geometry and Astronomy in the First Urbanization Period**

The First Urbanization Period is marked by the development of mathematical and astronomical knowledge for practical, religious, and administrative purposes. This emergence was deeply tied to agriculture, architecture, timekeeping, and religious beliefs. While each civilization contributed uniquely, there were commonalities in their approaches.

Geometry

Geometry arose from the necessity to measure land, construct buildings, and organize city layouts.

The Sumerians (c. 3000 BCE) developed a base-60 (sexagesimal) numerical system, which later influenced geometry. The Babylonians (c. 1900 BCE) recorded geometric principles on clay tablets, including the Pythagorean triplets (before Pythagoras!).

In Egypt, geometry was used for land division, city planning, and architecture (canals, irrigation). Egyptian geometry was highly practical, and linked to surveying, construction, and astronomy. The Rhind Mathematical Papyrus (c. 1650 BCE) contains calculations for area, volume, and fractions. Pyramids and temples demonstrate precise use of angles and proportions. After the annual Nile floods, land boundaries had to be re-measured for taxation, leading to advancements in surveying.

The Indus Valley was marked by Grid-Based Urban Planning. Mohenjo-Daro and Harappa (both in present-day Pakistan), Dholavira and Rakhigarhi (c. 2500 BCE) show advanced city layouts with precise right angles. The streets were laid out in a grid pattern, suggesting knowledge of measurement and geometry. Standardized brick sizes across the civilization imply mathematical precision.

The Egyptian and Mesopotamian traditions influenced later Greek geometry (e.g., Euclid, Pythagoras), while the Indus Valley's standardization foreshadowed later advancements in measurement systems.

Astronomy

Astronomy was closely linked to calendars and agriculture in all three civilizations and to religious beliefs in Egypt and Mesopotamia.

The Mesopotamians systematically recorded celestial movements on clay tablets. They divided the sky into zodiacal constellations, forming the basis of astrology. They also used a lunar calendar with 12 months, adjusting with leap months, developed early star catalogs (e.g., the MUL.APIN tablet, c. 1300 BCE), and observed planetary movements, influencing later Greek and Islamic astronomy.

The Egyptians created the first known solar calendar (365 days). The Great Pyramid of Giza (c. 2600 BCE) aligns with celestial bodies, particularly Orion’s Belt and Sirius. The rising of Sirius (Sothis) predicted the annual Nile flood, critical for agriculture. Obelisks and temples were aligned with the sun and stars, emphasizing cosmic order (Ma'at).

The Indus cities likely used astronomy for seasonal agricultural cycles. Artifacts such as astronomical symbols on seals also hint at early star observations and suggest potential links to early Hindu astronomy and Vedic rituals. Some Indus structures align with the summer and winter solstices, indicating awareness of solar movements. The Great Bath of Mohenjo-Daro, one of the earliest waterproof structures, may have had ritualistic cleansing tied to solar or lunar cycles.

Thus, the First Urbanization Period established key mathematical and astronomical concepts that shaped later civilizations. The Mesopotamians pioneered mathematical astronomy and early trigonometry, the Egyptians perfected surveying, architecture, and solar-based timekeeping, while the Indus Valley cities demonstrated mathematical precision in urban planning.

Though fewer astronomical records survive compared to Mesopotamia and Egypt, several findings suggest that the Indus people studied celestial patterns for timekeeping, agriculture, and religious purposes.

Lothal, a major port city, had a tidal dockyard that may have used lunar cycles for navigation. Early sailors likely tracked the moon’s phases for maritime trade.

Several Indus seals feature what appear to be star-like symbols, crescent moons, and solar discs, suggestive of a connection to early astrological beliefs. A frequently depicted figure with horns (possibly an early form of Shiva or Pashupati) might symbolize the crescent moon, an astronomical marker.

Some scholars believe that the Indus Valley people followed a lunisolar calendar similar to early Vedic timekeeping. Later Indian texts (e.g., Vedanga Jyotisha, c.

1400 BCE) describe Nakshatras (lunar mansions) and the sidereal year. These ideas may have originated in the Indus Valley, and later absorbed into Vedic knowledge. Thus, the roots of Indian astronomy might be traced back to the Indus civilization.

Krittika rises in the East.

Interestingly, the Satapatha Brahmana (a commentary on the Śukla Yajurveda) mentions several times that, unlike other asterisms, Krittika (the star cluster Pleiades) rises exactly in the East and does not move away from the eastern quarter. Was this based on observations made at that time? Astronomical calculations suggest otherwise-- Krittika did not rise due east in Vedic times.

According to modern astronomical calculations, the Krittika would have risen almost exactly due East around 2850 BCE to 3000 BCE coinciding precisely with the peak of the Indus Valley Civilization. The Vedic references therefore almost certainly seem to refer to observations made at earlier times.

The position of stars relative to the cardinal directions changes over thousands of years because of something known as the ‘precession of the equinoxes, i.e. a slow shifting of the equinoxes along the ecliptic. This was first discovered by the ancient Greek astronomer Hipparchus of Nicaea around 129 BCE. He noticed that the positions of stars, particularly the bright star Spica, had shifted compared to earlier Babylonian star charts. By comparing his own observations with older records, he determined that the equinoxes were slowly moving westward along the ecliptic.

This phenomenon, now understood as a result of Earth's axial precession, occurs due to gravitational forces exerted by the Sun and Moon on Earth's equatorial bulge, causing the orientation of Earth's axis to shift over approximately 26,000 years.

Some researchers argue that references in the Vedanga Jyotisha to the movement of the celestial bodies and the positioning of key stars relative to the seasons might hint at an awareness of long-term changes in the sky. Since precession causes the equinoxes to shift over thousands of years, some hymns describing cosmic cycles could be interpreted in this context.

The Satapatha Brahmana does not explicitly mention precession, but it does refer to different pole stars (Dhruva), which could indicate an awareness of the slow movement of the celestial north over long periods.

Later Vedic and Puranic texts, especially those discussing Yuga cycles, might encode knowledge related to precession. Some scholars suggest that the shifting of the Krittika from the vernal equinox in earlier periods to later positions could be an indirect acknowledgment of precession.

Other scholars argue that ancient Indian astronomers, such as those behind the Vedanga Jyotisha (circa 1200 BCE), were aware of long-term astronomical cycles, including precession, though they did not calculate them precisely.

Still others believe that precession was more explicitly recognized much later by Indian astronomers like Aryabhata (5th century CE) and Varāhamihira (6th century CE), who discussed planetary motions in detail.

In summary, while the Satapatha Brahmana does not explicitly describe precession as Hipparchus did, certain verses may hint at an early observational awareness of slow celestial shifts that were later understood as axial precession.

Mathematics

The Indus Valley Civilization (c. 3300–1300 BCE) covered an area of about 1,250,000 square km, comprising the whole of modern-day Pakistan and parts of modern-day India and Afghanistan. The civilization is thought to have had a population of upward of 5 million, and its territory stretched over 900 miles (1,500 km) along the Indus River. Though less is known about its intellectual traditions compared to Mesopotamia and Egypt (due to the undeciphered Indus script), archaeological evidence suggests that mathematics and astronomy played a significant role in its society, particularly in urban planning, measurement systems, and standardized weights.

Excavations at Harappa, Mohenjo-Daro, and Lothal reveal a highly uniform system of weights and measures. Cubical weights, made of chert, follow a binary and decimal system, with weight ratios of 1:2:4:8:16, similar to modern metric systems. A finely marked ruler (scale) from Lothal suggests precise length measurement (with divisions as small as 1.32 inches or 33.5 mm). This unit matches later units found in early Vedic texts. This implies a standard measurement system and an organized trade and governance. It also reflects early concepts of arithmetic and proportionality.

The Indus Valley cities were carefully planned using geometric principles like grid layouts. The Mohenjo-Daro, Harappa, and Dholavira were built with straight roads at right angles, forming a perfect grid system. The houses were arranged in rectangular blocks, indicating knowledge of right-angled triangles. Bricks used across the civilization followed a standardized ratio of 4:2:1. This uniformity hints at mathematical regulations in construction.

These cities stand as mute evidence of an engineering marvel-- underground drainage networks using carefully proportioned slopes and gradients to manage wastewater. Covered underground drainage ran beneath streets. Household wastewater was directed into brick-lined drains. Public baths and private wells ensured access to clean water. This was perhaps the earliest use of geometry in civil engineering and a possible mathematical code for city planning, similar to later Vaastu Shastra principles in Indian architecture.

This is centuries ahead of Roman aqueducts (500 BCE) and medieval sanitation (1000 CE), suggesting advanced hydraulic engineering.

4. **Cultural Influence of IVC on Other Civilizations**

Even though the Indus script remains undeciphered, there are strong cultural and intellectual links between the Indus Valley and later Indian, Mesopotamian, and possibly even Greek civilizations.

The Indus Valley planning principles influenced later Hindu architectural traditions. The decimal system and standardized weights found in the Indus Valley are seen in Vedic texts (Rigveda, Sulbasutras). The grid system in Indus cities resembles the Vaastu Purusha Mandala, the architectural framework of Hindu temples and cities.

The Sulbasutras (c. 800 BCE) describe geometrical constructions, similar to Indus Valley city planning. We will return to this topic in the Appendix.

The Indus Valley Civilization was also one of the most economically active and connected cultures of the ancient world. It engaged in extensive trade with Mesopotamia, Central Asia, Oman, Bahrein (ancient Dilmun), Persia (modern Iran), Afghanistan, and perhaps also East Africa. They used primarily overland trade routes. Land caravans (oxen-drawn carts) were used to transport goods northward. The Bolān and Khyber Passes were important routes from the Indus Valley to Central Asia.

Mesopotamian records mention trade with a land called "Meluhha"—believed to be the Indus Valley Civilization. Indus seals found in Ur, Sumer, and Akkadian sites indicate economic exchanges.

Mesopotamian cuneiform tablets use a base-60 numerical system that might have had some cross-influence with Indus decimal weights.

Several Indus seals have been found in Ur, Akkad, and Sumerian trading centers. These seals may have been used as merchant identifiers or legal trade stamps.

The Indus Valley standardization system predates Greek geometric formulations. The right-angled triangles used in Indus city grids resemble the later Pythagorean theorem.

Indus-style pottery has been found in Oman and Bahrain, suggesting maritime trade routes. Copper ingots from Oman contain Indus Valley markings, possibly indicating metal trade.

Some evidence suggests shells and exotic African goods reached the Indus Valley. The Indus people may have imported African ivory and certain hardwoods. This is indicative of one of the earliest maritime trading networks, possibly influencing later Indian Ocean trade.

5. **Decline and Continuity of IVC**

The Indus Valley Civilization mysteriously declined around 1900 BCE. Several factors might have contributed to its decline.

Climate Change & River Shifts

One of the most accepted theories suggests that climate change led to a decline in agriculture.

Once a major river, the Saraswati is believed to have gradually disappeared around 2000 BCE. There were also shifts in the Indus River. Flooding and river course changes could have disrupted cities and farming.

Drought and Monsoon Weakening

Yet another cause might have been drought and Monsoon weakening. A shift in monsoon patterns may have caused agricultural collapse, and decreased food production could have led to famine, population decline, and migration.

Disruptions in trade networks

Disruptions in Mesopotamia may also have had further weakened the Indus economy.

Possible Aryan Invasion Theory

Some historians once suggested that Indo-Aryans invaded the Indus cities and caused their collapse (based on the Rigveda's references to battles). However, this theory has been disputed because there is no evidence of large-scale warfare or destruction in the Indus cities, and the decline appears to have been gradual rather than sudden.

Some scholars believe Indo-Aryans may have migrated into a weakened Indus region and gradually assimilated.

Possible Social and Political Decline

There are some indications of social and political decline. Strikingly, no large palaces, kings, or centralized authority have been found in the IVC, unlike in Egypt and Mesopotamia. Hence, Indus cities might have been governed by merchants or local councils. The lack of strong leadership may have made them vulnerable to decline. Hence, as trade and agriculture failed, cities were probably abandoned.

Small rural communities however survived, but large cities never recovered

Despite its decline, the Indus trade laid the foundation for later South Asian commerce, influencing Vedic civilization, the Silk Route trade, and even maritime trade in the Indian Ocean.

Indus cultural and mathematical traditions also survived in later Indian civilizations. For example, Harappan weights appeared in later Gangetic culture (Vedic period, c. 1500 BCE), and city planning techniques persisted in Mauryan (300 BCE) and Gupta (400 CE) cities.

Vedic rituals and temple layouts may also have evolved from Indus religious structures.

The Indus Valley Civilization was not just an urban culture—it was an early center of mathematical, engineering, and scientific thought. Its cultural Influence included contributions to Indian science, Mesopotamian trade, and possibly Greek geometry.

Even though we have no deciphered texts, the planned cities in the Indus Valley stand as irrefutable archaeological evidence of unprecedented architectural and mathematical innovations.

Rakhigarhi

Although the great cities declined, the Indus people did not disappear. Instead, they migrated and adapted. Many Indus people moved eastward towards the Gangetic plains, influencing early Vedic cultures. The recent discoveries in Rakhigarhi support this view. Rakhigarhi provides significant evidence supporting the continuity of the Indus Valley Civilization (IVC) into later South Asian cultures. Excavations at the site reveal that many cultural practices—such as pottery styles, town planning, and agricultural techniques—persisted beyond the decline of the urban phase of the IVC (around 1900 BCE).

Recent DNA studies from Rakhigarhi suggest a genetic continuity between the Harappans and later South Asian populations, indicating that the people of the region did not disappear but rather evolved into later societies. Additionally, certain traditions, such as the use of specific motifs in pottery, burial practices, and even aspects of religious symbolism, show continuity with later Vedic and modern Indian cultural elements.

Even to this day, life in the villages around Rakhigarhi offers a direct glimpse of life in the Indus Valley during its heydays.

Appendix: The Śulbasūtras

The Śulbasūtras are a collection of ancient Indian texts, written between 800 BCE and 200 CE, that primarily deal with geometric principles used in Vedic rituals. These texts are part of the larger corpus of the Kalpa Sūtras, which provide instructions for constructing altars and fire pits with precise measurements to ensure their alignment with religious and cosmic principles. The most prominent among the Śulbasūtras were composed by sages such as Baudhāyana, Āpastamba, Mānava, and Kātyāyana.

One of the key mathematical contributions of the Śulbasūtras is their approximation of the square root of 2. The Baudhāyana Śulbasūtra provides the value 1.414215

These texts also contain early instances of the Pythagorean theorem, centuries before it was formally stated in Greek mathematics. The Baudhāyana Śulbasūtra, for instance, states that in a right-angled triangle, "the diagonal of a rectangle produces the combined areas of both squares on its two sides," which is a direct formulation of the theorem. This principle was crucial in constructing perpendicular lines for altars.

They also contain a wealth of geometrical constructions that were primarily developed for the precise layout of Vedic ritual altars (yajña-vedis). These constructions reflect an advanced understanding of geometry, particularly in the context of ensuring accurate proportions and alignment with cosmological principles.

The Śulbasūtras also provide instructions for transforming one shape into another while preserving the area. For example:

• Converting a square into a rectangle or vice versa.

• Converting a square into a circle with approximately equal area, leading to an early approximation of π.

• Doubling the area of a square (dvisuvarna), an exercise that resembles the classical Greek problem of "doubling the cube."

The texts detail the construction of increasingly complex altar shapes, such as falcon-shaped and circular altars, which required intricate geometric calculations. The precision involved indicates a strong mathematical tradition, likely developed through both theoretical reasoning and practical applications. All these demonstrate the applied nature of mathematics in ancient India, where geometry was developed not just for abstract reasoning but for practical and ritualistic purposes. These texts stand as a testament to early mathematical ingenuity, influencing later developments in both Indian and global mathematical traditions.

The Vedic Period (1500–500 BCE) marks the transition between the decline of the Indus Valley Civilization and the onset of the Iron Age. This era is named after the Vedas, the oldest sacred texts of Hinduism, which were composed during this time. Early Vedic society was predominantly pastoral, gradually evolving into an agrarian culture. Unlike the urbanized Indus Valley Civilization, the Vedic period left no archaeological evidence of large cities or constructed ritualistic altars. Consequently, it is unlikely that practical geometry was developed during this era. Instead, it is more plausible that the mathematical knowledge found in the *Śulbasūtras*, a part of the Vedas, was inherited from the earlier Indus Valley Civilization and preserved through oral tradition by successive generations of sages.

A significant parallel to the mathematical traditions seen in the Śulbasūtras is found in the *Bakhshali Manuscript*, an ancient Indian mathematical text discovered in present-day Pakistan. The manuscript is kept at the Bodleian Library of the University of Oxford in England. It is an ancient Indian mathematical manuscript, written on birch bark, and is notable for containing the earliest known use of a symbol for zero.

Dated to a period between the 3rd and 10th centuries CE, the manuscript contains numerical calculations, including decimal place value notation and an early concept of zero. While the Bakhshali Manuscript focuses more on arithmetic and algebra rather than geometry, it demonstrates the continued evolution of mathematical thought in India. Together, these texts highlight the deep mathematical traditions of ancient India and their lasting influence on the development of mathematics worldwide.

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Suggested Illustrations

Photographs of pyramids and other structures in Egypt, the ziggurats in Mesopotamia, and the grid system of the cities in IVC (Harappa, Mahenjo-Daro, Dholavira, Rakhigarhi); the Great Bath at Mahenjo-Daro, toilets, drainage systems, etc; maps showing the geographical spread of IVC; dockyard in Lothal; Indus seals and beads, geometric constructions in the Sulbasutras, particularly illustrating the Pythagoras theorem