THE ISET PLATFORM LECTURE

BUILDING THE GREEN CITY OF FUTURE

"INCLUSIVE" TECHNOLOGIES AND MATERIALS

Sudarshan Raj Tiwari

Cities are a main source of economic activity and productivity. Today, almost half of the world's population lives in cities and this number is growing. In Asia alone, every day more than 100,000 people move to cities seeking a better life. It is estimated that within the next 15 years, 60 per cent of the world's people will live in cities, most of them in Asia. To accommodate all of them, it is clear that cities will have to function within the means of the environment and its resources. If cities are to be the foundation of human wellbeing, they must maintain clean air, clean water and green land as the key ingredients of livability. In a rapidly urbanizing future, how can the ecology of a particular city be balanced with the socio-economic development of that city? The pathway to livable green cities should be charted on a shared vision that brings together the wisdom offered by both western and eastern systems of knowledge.

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INTRODUCTION

The pace and scale of urbanization seen all over the world in recent decades highlights the urban character of our contemporary civilization. The future of most societies will be played out in cities. Our improved understanding of the changes happening in cities has brought out a startling truth: the impact of ecological changes in urban areas may be more pervasive than the impacts of social and economic changes. Indeed, urbanism is shaping up as the triangular relationship of nature, society, and economy. Just as the socio-cultural town of yore marched through the industrial era to find itself transformed into a socio-economic entity manifested as contemporary civilization, so now it seems poised to be transformed into a socio-ecological entity (e.g. Pelling, 2010; Dodman and Mitlin, 2011; Kates et al., 2012; Satterthwaite and Dodman, 2013) and Homo sapiens would become Homo sapiens urbanus (State of Cities, 2010).

In recent history, the impact of urban life on nature has been both unsettling and chilling. Cities have encroached upon prime agricultural land, forests, and wetlands, interfering with their provision of ecological services to urban residents. Disorderedly urban growth has converted regions around cities into haphazard settlements, disturbed agricultural and natural resource systems; increased environmental degradation, water scarcity, and social stress; and yielded land, water and air pollution as end products. Animal and plant species are dying and resources for living gradually depleting. In Nepal's capital Kathmandu haphazard urban expansion has overwhelmed the rich heritage and converted rivers and streams into sluggishly flowing cesspools. This situation is not what ancient Hindu philosophies, which praise the abundance of nature, envisioned:

ॐ पूर्णमदः पूर्णमिदं पूर्णात् पूर्णमुदच्यते । पूर्णस्य पूर्णमादाय पूर्ण मेवावशिष्यते ।।

Nature is full and complete, and so are we. From nature's richness our fullness comes forth. When a fullness is taken from that fullness, fullness itself remains.

(BRIHADARANYA UPANISHAD) VERSE 1

This verse suggests that nature and its ecosystems are in a state of perfect harmony. The understanding goes on to imply that it's human activities that have disturbed this harmony and degraded nature:

> ये यथा मां प्रपद्यन्ते तांस्तथैव भजाम्यहम् ।
>
> ***However one approaches nature, he or she will be rewarded the same way.***
>
> (BHAGAVATAGITA. 4.11) VERSE 2

Since those days of the *Veda*, a time that joyfully invoked the song of plenitude, human progress seems to have plunged headlong along the wrong path, a path of degradation and scarcity that leads away from nature.

Our current disregard of nature when we build our cities and chose technologies and materials is the wrong approach. If the wrong is to be corrected, a city can no longer separate its dwellers from nature: an urban dweller is as much a part of nature as he or she is of a society and its economy. Indeed, the more we experience and understand the problems of urban systems, the more we realise we must co-exist with nature. Making such a change will require us to fundamentally redesign our present material use, technological choice, lifestyles, and approach to urban development.

While, as a new stressor, climate change complicates the tasks of making such a change, it can also be a window of opportunity. The melting of polar ice caps, snow packs, and glaciers and erratic precipitation associated with climate change create unanticipated sources of vulnerabilities for lives and livelihoods. These and other impacts on urban settlements and dwellers have widened the disjunction between cities and nature, but they ought to force us to re-imagine future green cities and the green lifestyles they make possible as living systems with ecologically clean technologies, resilient infrastructure, and compact and mixed land use. Building the green cities of the future require us to recognize that nature is both comprehensive and universal, just as it always has been. This pathway will further demand transitioning of building materials and technology at a fundamental level.

Nature, Knowledge and Agents

As cities developed, planners sought to maximize natural resource throughout using scientific knowledge. They considered the city as distinct from the countryside and problematized urban environment. Indeed the central approach of modern science has been to break a phenomenon (For example, a city or entities within a city) into distinct components (disciplines), isolate those components from their larger context, identify processes to frame specific questions and seek answers. This approach has served science and society well (and will continue to do so), but the capacity of this paradigm to contribute effectively to addressing complex ecological challenges is evidently limited.

Addressing these challenges require perspectives from many disciplines, multiple jurisdictions and management objectives, and concerns with cause and effect over large spatial scales and long timeframes. In the face of such challenges, conventional approaches to scientific analysis are found inadequate, particularly with regard to its ability to predict consequences and effects. Today it is becoming increasingly clear that the rural and urban no longer exist as separate entities but as two ends of a continuum. What does such a continuum mean for the green city of the future? How do we re-imagine cities, towns, urban settlements and their hinterlands in the dynamic context of rapid change? Is it ecologically wise to limit urban nature within just the urban-rural continuum? Scientists have defined nature in much wider extents and give us options of containing eco-systems e.g. continuum of space-time or energy and matter. As we attempt to examine and answer these questions, knowledge and knowledge agents (individuals) emerge as central elements.

Eastern philosophies have long recognized that knowledge is made up of the experiences felt through our five bodily senses and perceived through the five differentiating sheaths of our minds, *kaal, kala, vidhya, maya* and *niyati*.[1] The treatises suggest that it is the knowledge body of knower that gives rise to, nurtures, and maintains the sky, which contains all the other four elements. The *Gopatha Brahmana of Atharva Veda* explains this basic interrelation in its identification of the twelve ambient elements, the *mahabhuta*:[2]

[1] Translates as time, scale, accrued knowledge, attachment and natural intent respectively.
[2] Knowledge, sky, air, energy, water, earth, cereal, life, mind, sound, oral *veda* and *yagna*. The quintet of the *mahabhuta* (sky, air, energy, water and earth) is well known.

ब्रह्मण आकाशंभिपन्नं, ग्रासितं परामृष्टम्, आकाशेन वायुरभिपन्नो ग्रासित:
परामृष्टो, वायुना ज्योतिरभिपन्नं ग्रासितं परामृष्टम् ।
ज्योतिफायो भिपन्ना ग्रासिता: परामृष्टा ।
अदिभर्भ "भिरभिपन्ना ग्रासिता परामृष्टा, भुम्यान्नभिपन्नं ग्रासितं
परामृष्म् अन्नेन प्राणो भिपन्नोग्रासित: परामृष्ट: ।

Knowledge gives rise to, nurtures and assures the continuance of the sky. Air arises in the sky and is consumed and wholly contained by it. Air gives rise to, consumes and wholly contains energy. In energy, water is expressed, consumed, and contained wholly. In water it is the land which is expressed, consumed and contained wholly. In the land cereal is expressed, consumed and contained wholly. In cereal life is expressed, consumed and contained wholly.

(GOPATHA BRAHMANA) VERSE 3

The verse suggests the sequence of the *panchatatvic* the five elements making the environmental envelope and defines the universal ecosystem as the mix and interpenetration of one element into the other e.g. earth is expressed in water, water in fire, fire in air, and air in sky. Also, we find another verse in the same *Brahmana* that indicates some out of sequence interrelation, e.g. that where there is fire, there is earth and where there is earth there is fire. Fire and earth cohabit as a couple, as this verse, which also seems to present advance knowledge of global warming, suggests:

अग्निरेव सविता पृथ्वी सावित्री यत्र होवाग्निस्तत्पृथ्वी ।
यत्र वै पृथ्वी तदग्निरिति एते द्वे योनि एक मिथुनमा ।।

Heat is like the mover and earth, the simulator. Where there is heat, there is earth; and where there is earth, heat will nest. The two wombs make a single couple.

(GOPATHA BRAHMANA) VERSE 4

Another *gayatri* verse depicts the sky and the air as a couple too. At this stage in understanding of such esoteric texts, we cannot say what observations or perceptions led the creator of the verse to philosophize that water is expressed in fire and fire in air or to infer the coupling of earth and fire and air and sky in

order to explain the nature of the environment. It is nonetheless amazing that the relationships among different elements expressed in these verses match well with those emerging from the current experience of global ecological imbalances in the interplay of earth, water, heat and air. It is evident that water befriends all other elements and is present in three of them.

The marvel called the tree

The centrality of the tree in this telescoped principle of the ultimate nature (verse 3) is repeated in several other elaborations of Hindu philosophy. It is around the earth tree (the *achala* or fixed life form group) that animals (the *chala* or moving life form group, the group which includes humans) build their lives and settlements. The wisdom ensconced in the earth tree has the potential to be a savior and prime mover of our future urban systems. We can use this knowledge to design effective plans, technologies and materials to build the green cities of the future.

It is common knowledge that without plant life on Earth, there would be no oxygen in the air and that without oxygen there would be no animal life. The two life forms, the animal and the botanical, one inhaling oxygen and exhaling carbon dioxide and the other taking in carbon dioxide and releasing oxygen, between them have kept the atmosphere dynamic, balanced and suitable for life.

But the workings of the tree go beyond that of making the air breathable. Trees live and interact with all five elements and environmental entities (*tattva* and *mahabhuta*) of space, air, energy, water and land. According to *Gopatha Brahmana*, the tree occupies a singular position in nature:

... वायुम अभ्रम्, अभ्रमेण वर्ष्म्, वर्ष्णेौषधि-वनस्पतीन्, औषधि-वनस्पतिभिः पशुन्,... ..
संशितो भवति अशुन्यो भवत्यविच्छिन्नो भवति ।

... In cloud is rain realized, nourished to fullness and continued. From rain, herbs and plants are materialized and, nourished to fullness, and obtain survival. From herbs and plants are animals materialized and nourished to fullness and obtain survival.

(GOPATHA BRAHMANA) VERSE 5

As the verse 5 explains, plants hold the key to the growth, preservation and continuity of all biological entities. Plants can process sunlight into the energy needed to sustain life. Animal life depends on air, moisture, and plants for survival. Whether they live in cities or in caves, humans need air, moisture and plants. Of these it is plants, which meet humans' needs for biological energy.

Trees are indeed marvelous life forms. Fixed on the ground, they cannot move to search for food, protect themselves from the whims of nature, have sexual relations to procreate, or exercise to keep fit. Yet, the tree lives in harmony with nature. A closer look at the functioning of the tree is particularly worthwhile because the notion of green city is based on the greenness of tree. The tree is rooted in the moist earth and stands upright in the air. It comes in physical contact and interacts continuously with all five elements—sky, air, energy, water and earth—in interconnected ways. Rooted to the ground, the tree uses the motive forces available in wind and birds to pollinate and thereby propagate itself. In the process, it dances with the wind and keeps fit by swinging with storms.

One of the most marvelous acts that the tree performs is photosynthesis. Chlorophyll in its leaves not only makes it look green but synthesizes solar energy into organic energy that is stored in its other parts and its fruits. It draws the carbon and hydrogen it requires to function from the air and water respectively. This process evolved by the leaf of the plant is what I call 'inclusive technology' as it integrates all five elements to nourish the plant while at the same time recycling all the by-products into other natural cycles available to it. It is astonishing that the water that a tree needs for photosynthesis can be drawn only from moisture stored in the earth. The leaf, though able to transpire, cannot partake of the moisture in the air. Trees help keep air moist but they themselves have no direct use for this moisture. The leaf of the tree is unable to do much with atmospheric ambient heat either and has learnt to wilt in unmanageably hot circumstances. When heat is excessive, cold extreme, moisture content too high or too low, leaves may fall off the tree system altogether. They enter the cycle of nourishment with the earth acting as the medium of exchange.

The tree also keeps the earth moist and cools the earth without retaining the heat needed in the system. The tree links the energy, food and waste chains to its own preservation and to the preservation of the surrounding environment. It sequesters carbon dioxide in the air to replenish its oxygen and to maintain the food chain. The co-evolutionary processes in nature, of which the tree is a part, helps it offer bounties to humans and animals. Trees provide space to live to the birds that find shelter in them. Trees leave no waste.

The sequencing of interaction, mix, interpenetration and interrelation of the elements and the envelopes in Nature (verse 3) and their workings and place in the basic ecological cycle (verse 5) could provide the basis for re-imaging the principles of urban planning, selection of materials and of technologies through a fundamental shift in ecological results objectives. Verse 3 provides an important understanding of the position and interpenetration of the elements that make up any eco-system in nature, while, verse 5 shows the first right of trees to partake of rain. Clearly animals consume water only after the thirst of trees are quenched. The tree[3] can only use rain held in the form of moisture in earth by drawing it in through its roots. If this air-cloud-rain-earth-tree cycle is the natural cycle of water, then the ecological management of rainwater must be routed through the recharging ground and not "harvested" from the air. Only with such a system can we continue to let the tree and the land have a central role in the management and storage of water. It can be argued that our tampering with this cycle is one reason for many of our current ecological woes.

I believe that further analysis of the remaining verses will provide us with a different knowledge base to plan for and select materials and technologies for buildings as well as for to use the built space ecologically.

Our house and our city – Built to exclude nature

Humans built houses to keep rain, moisture, wind, heat, and cold out and to keep him safe from other animals. As we moved to cities, we began to pave the ground with water-impervious materials and pipe water to our homes. We began creating elements that suited our desire for comfort. We use air conditioners that, in inverting the natural environment (cold in summer and warm in winter), represent a triumph over nature indeed. Born two-legged animals with ability to walk, we nonetheless invented wheels, wheelchairs, cars and lifts. With the last two technical contraptions, which Leon Krier called the two sanguine mistakes committed by modern man (Krier, 1998), we can now run and climb sitting! While the effects of these behaviors on our legs are for other forums to ponder, their effects on cities have been phenomenal, widespread sprawl both vertically and the horizontally.

[3] Interestingly termed *'padapa'* in Sanskrit, which means the entity group that drink through their feet!

In the process of such invention, however, we have excluded ourselves from the richness of our planet. We have concentrated wastes around the cities. First, we polluted the water, then the air, then the land and now we are even polluting the thermal environment through global warming. Four out of the five elements and environmental entities—water, air, land and heat—now lie polluted, a state attributable to the unassimilated, unprincipled and unsequenced mixing of materials and technology. With radio, electrical and other communicating waves, even that last region of the environmental envelope—space—is at risk of getting polluted. Instead of living with nature, we have sought and continue to seek to exclude and conquer it for our benefit and comfort. The technological and material choices made have helped human civilization reach where it is today, but this pathway has incurred heavy ecological costs.

The city has become huge and tall but also desert-like, hot and grey. Cities which are built of materials weather in long time, and produce waste that nature is unable to assimilate on its own. Animals other than man have deserted the city, regardless of their habitat, land, water or air. With a socio economic realm that seeks to dominate by building a system that seeks to exclude as much of it as possible, our urban society has forgotten the value of nature. The house and the city have become the antithesis of the tree and the forest in principle, in form and function, and in material and technology use.

Learning inclusive technology from nature

Though we have about 6,000 years of experience living in towns, urbanism is an ecological infant. Natural ecology is a complex chain of interlinked, balanced and stable sub-systems and relationships among the elements of this system have played out for 4.2 billion years.[4] In stark contrast the urban ecology is just beginning to take form and shows a dynamism in which many sub-systems appear explorative and open-ended. Urbanism's key characteristic is concentrative as it systemically brings together both populations and economic activities. Urban ecology opens space for nurturing ideas and innovations, supports cultural hues and social colors, creates opportunities, offers services, sustains and even thrives on heterogeneity. Yet the present urban ecology is distant from the diffusive character of Nature and the principle observed in the five constituent elements and environmental entities—sky, air,

[4] This is according to Western estimates. Hindu calendars put the age at only 1.95 billion years.

energy, water and earth—that make up the physical world. The technologies we have chosen for living and servicing urban life, including building materials and other systems, have been developed as cycles of inputs of energy and materials and outputs of targets and waste. This choice is not linked to natural processes or to other living and non-living elements of nature. Resource use at the input, process and output stages have led to the concentration of waste in the five elements of nature within which urban space is evolving. Not only have we learned nothing from the ways of nature, but we have also exceeded the capacity of nature to disarm the wastes that urban lifestyles and processes put into its fold. The interactive, supportive and interpenetrating characteristics of nature are missing from the present urban scheme of things.

Nature has nurtured, developed and continued only those technologies which use the output of other natural processes as inputs and whose products and process outcomes are partly assimilated that re-initiate process for new output. While putting the process in motion, each output becomes input for further cycles to be put into motion by agents in nature responsible for other outcomes. This waste-free approach of linking outputs to multiple users and usages (e.g. different life forms and their survival needs) makes nature green in more ways than one and we should not limit our understanding of green as just the colour of chlorophyll. Nature instills "chlorophyll" property of myriad kinds in its action points along its many ecological cycles. In nature, we can also see umpteen examples of process technologies that include roles for living forms and their metabolic systems making chains of co-optative sustainability.

The greening of a city would turn our un-ecological present around, and ensure that its interaction with nature, its economic functioning and its social construct would be changed to function like a tree, that is, using solar energy and sharing its benefits with all other life and plant forms. Greening a city is about maintaining harmony with nature and its air, water and land cycles while at the same time using materials and methods that respect and work with nature. The other indicators of a green city are cool and processes that keep things moist, cool and green are natural ways to deal with present urban state which is dry, hot and grey. Thus humans can live in harmony with other life forms.

The ancient wisdom has suggested that "the earth becomes the abode of all beings because of the sun" (Manasara, 3.14). This wisdom has been vindicated by the modern explanation that "life on earth would not exist without the sun" (Morishima, 2010, p. 108). In point of fact, life on Earth would not exist not only if there were no sun but also if any of the four other elements—air, water, land and space—were missing. Morishima (2010, 127-128) concludes that "we

must become aware of the importance of learning from nature, and develop science and technology, not to conquer and change nature as we did in the past, but to transform it and use in ways that will enable us to develop nature in harmony with the natural world."

Learning about inclusive materials from nature

Modern science characterizes good building materials in terms of their compressive and tensile strengths; hardness and brittleness; failure under stress and strain; electrical, magnetic, optical and thermal properties; resistance to corrosion' and temperature stresses. Using the logic of abundance, building materials were expected to be based on the eight elements that make up as much as 98% of the observable portion of Earth's land surface—oxygen, silicon, aluminum, iron, calcium, sodium, potassium and magnesium. Traditionally, as building materials, the oxides, silicates, calcite and kaolinite (minerals, rocks, sand, and clay) have dominated. Today, metals, ceramics and polymers (natural or man-made) make up the majority of construction materials as an examination of any modern building demonstrates. Durability attained through strength and resistance to natural weathering has come to be the most desired characteristics of this material. Since the presence of water is key to weathering in nature, science and technology sees water as the number one enemy of material durability. How unnatural like the technologies and tools developed on such a premise is made clear by reflecting on the fact that no life is possible without water. Such an approach can only lead to un-ecological states.

Vedic wisdom highlighted the interpenetration and interdependence of animal and plant life and the five elements of land, water, heat, air and space as material and environmental entities in the totality of nature. Any material, which is found on, in or over land or between land and space is subject to cutting, wetting, burning and drying according to the properties of the earth, water, heat and air respectively. All materials, therefore, deteriorate. Temporality and disposability are the essential qualities of all ecological materials, which initiate and keep all natural ecological processes going. Lord Krishna points to the only exception, the soul:

नैनं छिन्दन्ति शस्त्राणि नैनं दहति पावकः । न चैनं क्लेदयन्त्यापो न शोषयति मारुतः ।।

(The soul is) neither subject to cuts of arms nor burnt by heat nor wetted (made supple) by water, nor dried by air.

(BHAGAVATAGITA. 2.23) VERSE 6

This verse makes it clear that, in the worldview of the *panchatatvic*, for anything to be material it has to submit to the processes of cutting, heating, burning wetting, and drying, singly or in combination. In this scheme of things, any technology or material that demands or creates an unnatural situation, including one which is airless, a-thermal, fireproof, or waterproof, in absolute terms, has to be suspect of yielding un-ecological outcomes as such technologies and materials will curtail disposability, promote technological obsolescence and generate waste beyond the capacity of nature to digest. From this point of view, a material that thrives on an anti-life regime (no air, no heat, no fire, no water) is no material at all.

As Fitch has rightly noted "concepts of technological obsolescence, of objects becoming useless *economically* without reference to any residual *physical* utility, are modern inventions, the result of the industrial revolution" (Fitch, 1992, p. 30). Over recent years, the 'technology' industry has literally thrived on obsolescence. This technological revolution has led to the development and application of highly durable materials, establishing production of solid waste and use of materials that do not age or physically deteriorate over time as defining features of twentieth century urban development. There is a discrepancy between the durability of waste and the fast pace of technological development: while technological development has made the economic life of artifacts short, it has lengthened their physical life. Plastic bags, for example, have an economic life of an hour but a physical life of 1,000 or more years. Similarly, the economic life of a reinforced concrete building can be as low as 30 years in vibrant economies, but its structural life may reach 100 years and its physical life, several centuries.[5] The long residual physical lives of artifacts and materials far beyond their economic lives make waste pile up as, constituting a major liability to the assimilative capacity of the earth in the future. The profitability of the "tear–it-down-and–start-over" philosophy makes for the unprecedented waste of building materials in many urban-scapes. Only a century after the advent of the technological pathway, we already have giant junkyards of concrete rubble around towns and cities. Whether or not, ecologically speaking, the earth can tolerate the accumulation of physically durable materials with no economic value is a question of serious concern for the future. In the same way carbon emission that has become an unintended consequence of the industrial revolution, we must consider that such waste is a terrible side effect of urbanization as we know it.

[5] Some time ago, scientists at MIT reported that they were developing concrete that could, theoretically, last 16,000 years and that this material would be a marvel for engineering and technology. The horror that this mistakenly named 'green high-performance concrete' would be to the future of the city can be easily gauged.

There is an immediate need to develop engineering materials the disposability of which is deemed as important as their durability, strength and functional performance. Similarly, there is an urgent need to augment the porosity of material to water so that currently employed water-excluding systems are replaced by inclusive ones at appropriate points. Unless water-inclusive materials and technologies are used in the buildings and systems that service a city, modern technologies cannot possibly develop ecological loop.

Conclusion

I would like to explore the possibilities offered by three traditional technologies used in Kathmandu's building and city tradition as we begin to transit to green cities with inclusive technology.

(1) *Jhingati*, the porous roof tile

Valley residents showed a preference for 'inclusive' materials and technology that objectively allowed rain to go its own way as long as it did not damage the roof or hamper its function. The *jhingati* is a single locking unglazed baked clay tile traditionally used as roofing material in Kathmandu Valley. The tile was laid on a layer of mud spread over timber slats themselves laid on timber rafters. The thickness of this layer ranged from five to as much as thirty centimeters, depending upon the possible depth of wetting. The objective, it seems, was not to make a waterproof roof but use the mud to prevent wetness from reaching the timber slats and rafters and damage it. The inclusion of the cycle of the wetting and drying of mud, a natural behavior linking sun and rain, into building performance is a lesson in living with nature. Keeping the underside of the tile dry was simply not a desired outcome. For a society, which discovered the glazing of terracotta surface quite early, produced 'impervious' bricks and brickwork, and used sheet copper for roofing, the use of porous tiles for roofing palaces and residences exposed to monsoon rains, is hardly surprising.

(2) *Dachi-apa*, bricks glazed with moss

Troubled by the wetting of porous bricks and quick deterioration of adjacent carved woodwork, Kathmandu Valley builders developed a wedge-shaped high-density glazed brick that almost totally stopped the wetting of not only the brick but also of the mortar and the brickwork as a whole. The glazing technique used was not the process of sintering or fusion followed by most cultures, a process which results in structural changes in the material through the application of heat. Instead, exposed brick faces were slip-glazed using reddish moss, a microscopic material generated by the action of water on

vegetable waste such as straw and matured over years. The glaze of the *dachi-apa* is so strong that centuries of actions by water are unable to deteriorate the brick. This durability is due to the fact that the finishing material itself was generated by the action of water. As in the case of the *jhingati*, the protection of woodcarving from moisture appears to be the main motive of the technology. Both the water-resistant material and the technology developed were learnt from observations of the natural act of water itself.

(3) Snakes to maintain the deep drains of pit conduits

As early as the sixth century CE, towns in Kathmandu Valley had an urban water supply system consisting of deep pit conduits located at street crossings. Although the supply side of the water system was simple in its use of gravity flow and, as a result, deep pit structures to house the supply outlet, the construction of the drainage canals at such depth demands complex knowhow. Still more amazing is the fact that these deep wastewater drainage channels were virtually maintenance-free and worked perfectly for more than a millennium until modern civilization sent plastic waste floating into the innards of the system. They were not, in fact, maintenance-free: zoological crews assumed the burden. Tradition has it that fish and snakes were left in the waters of the pits as a humane way of disposing of them and that these creatures kept the drains clean. It is said that as plankton grew, fish feasted on it. Frogs then came to live, feasting on fish. And finally snakes, in their turn, chased and swallowed frogs down the drainage channels to come out at the riverside end, leaving the channels clean. What better way of sharing urban services with other animals can one imagine?

The idea inherent in the three traditional technologies presents possibilities to examine pathways as we attempt to address urban challenges. If our cities are to be green, livable and smarter than present there is no alternative but to bring together the values and ideas articulated in Eastern verses and the analytical rigor of modern science.

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Brihadaryanya Upanishad

Gopatha Brahmana

Bhagavatagita

Manasara

Born at Bishalnagar in Kathmandu in 1950, Sudarshan Raj Tiwari studied architecture and earned Bachelor's degree from School of Planning and Architecture, University of Delhi, in 1973. He took his Master's degree in Architecture from the University of Hawaii, USA in 1977, specialising on housing in tropical countries. He received PhD from Tribhuvan University for his dissertation on ancient settlements of the Kathmandu Valley in 1995. He has served in the faculty of Tribhuvan University's Institute of Engineering Department of Architecture for almost 40 years, and was Dean of the Institute of Engineering between 1988 and 1992. Among his published works are: The Brick and the Bull: An account of Handigaun, the ancient capital of Nepal (2001) and Temples of Nepal Valley (2009). He is working on a book on Bhaktapur at present.

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