‘Play with complexity’ in the context of rapid change with scarce resources

Askok Lall, Guru Gobind Singh Indraprastha University (GGSIU); Ashok B. Lall Architects, India

As I look up toward the need and the challenge of reinventing construction through the window of “Play with complexity”, the catch phrase that defines the theme of this particular stream of Re-inventing Construction, I do so from a particular location within the real world. This location is a world of “Rapid Change with Scarce Resources” [1], a condition that characterizes much of what is happening today in the “emerging” economies of the world today. In this paper, however, I will be referring to India with which I am more familiar, with the expectation that its case will be relevant to many other parts of the world too.

1 Context

The rapid change that is sweeping across India is a consequence of the shift of the economy from an agrarian toward an urban base resulting in its increasing populations moving into cities.[2] There is a growing, educated middle class which is aspiring to a higher standard of living. There is also a large poor population, living in abject conditions in informal settlements I and around cities. They have no capital, possess only basic skills. They are seeking a secure foothold in the urban economy. The building industry is a significant part of the urban economy[3]. While it is a generator of wealth it is also a large employer of the urban poor and therefore it is a potential distributor of wealth too. Meanwhile income disparity is growing. This trend is not socially sustainable.

The consumption of energy in the making of buildings and in their operation is on the rise. This is the result of a combination of factors: new aspirations and changing lifestyles of the middle class, and the fact that the conditions of building in cities become necessarily more energy intensive compared to traditional ways of building. New building stock is being added at an unprecedented rate. There is a prediction of the existing building stock being doubled in the next two decades[4]. This puts an enormous pressure on available natural resources. And this phenomenon of compressing so much construction into a short time will be like an explosion of CO2 emissions on account of the energy embodied in the production of building materials alone. This is of immediate concern. The rise in the operational energy demand is a subsequent concern, a wild fire that trails the explosion.

2 Necessity of Innovation

Reinventing construction is indeed a necessity. Traditional ways of building, though they were largely sustainable in themselves, cannot meet the new demands of urban living. In today’s cities we need - to build to higher densities while ensuring safety against earthquakes, typhoons and fire; improve lifecycle performance of components and finishes; and raise efficiencies in utilization of material resources while reducing the embodied energy in the construction of new buildings. We need to meet the expectations of better environmental performance in buildings – thermal comfort, illumination and air quality – in conditions of dense urban development with growing air and noise pollution, located in a predominantly hot climate. These we must serve while curtailing operational energy consumption. As a rough measure I propose that the sustainable target for energy consumption in embodied energy in building construction could be 80% of the current consumption pattern in cities in India[5]. For operational energy, allowing for the expected rise in the standard of living and anticipating life-style changes of the urban middle class, the target energy consumption need not increase beyond 15% above the current average energy consumption in buildings per capita of the urban population.

Just as it is inconceivable that all of us in India will rise to the levels of consumption of Western Europe, it is equally unlikely that that the majority of our citizens can afford the new cutting edge solutions being developed in the wealthier parts of the world from an elaborate technologically advanced platform – highly processed light-weight skins, multilayered envelopes with integral controls to adjust thermal, illumination and ventilation functions, automated electro-mechanical equipment etc. Our challenge of "Reinventing Construction", then, is to devise ways of building and ways of using buildings that serve rising aspirations, while achieving higher efficiencies in the use of material resources and energy, **within the framework of real affordability – better quality, higher efficiency of performance, at low cost.**

3 Engine of Wealth Creation and Wealth Distribution

Further, if we recall that the building industry is a substantial chunk of the economy of cities, the new ways of building need to be the engine that distributes income more equitably and not one that ends up concentrating wealth in few hands. This engine of wealth production requires innovation that adds value to human resource to leverage a more equitable distribution of wealth. And this process has to be built up largely from the platform of the available technological infrastructure and financial resources.

4 Viewing Lenses

Let me presume that I have my feet firmly on the ground as I look up through the window.

To strategize re-invention I have used three lenses to help me see the picture holistically. The first lens is the idea of a **mind-body-tool continuum** to delineate the wider parameters of "complexity". The second lens is that of the **DNA of systems**, their robustness and responsiveness to change over time, as a measure of a sustainable complexity. And the third lens is the **socio-economics of innovation** according to the location of the innovator in the building industry field - which stretches from materials development to complex assemblies and construction processes or from simple-tech to hi-tech.

This paper is an opportunity to attempt a strategic framework for reinventing construction that would be relevant to the needs of societies in rapid transition such as India. As a practicing architect, interested primarily in the practical realization of innovation I use examples of works that have been done and some that are in the pipeline that respond to the circumstances of "rapid change with scarce resources", and to test a strategic framework for reinventing construction for size.

5 Mind-Body-Tool Continuum

At the first Holcim Forum I had proposed a conceptual equation for environmental sustainability which included human need as a subjectively operable variable rather that a determined "standard". The conceptual equation serves as a reminder that if need is the progenitor of technology an enlightened definition of need is the first level of action toward sustainability.

The physical performance that we demand from buildings, commonly referred to as "standards", is the function of our definitions of safety, reliability, convenience, comfort and, today, energy efficiency. While the formalization of these considerations into codes and regulations is intended to protect and promote our well-being, their specificity at a particular time and place is a negotiation between cultural values and techno-economics. It could be said that the more rigorous and demanding these become the greater is their environmental cost, and as we work toward reducing environmental costs while meeting more rigorous demands with innovation of new technologies we incur higher techno-economic costs. Of course safety and reliability are less negotiable, but interestingly comfort and convenience provide ample room for exercise of choice, informed choice! Unfortunately, we see in building codes a tendency for "standards" being handed down for universal application, sometimes locking us into received rather than responsive technologies, at high cost. Instead, we would envisage innovations that devolve choice and responsibility to the user, the way we do for clothing.

We have learnt to apply this idea of a mind-body-tool continuum in bicycles and motorcars, in the pianoforte and the synthesizer, we now begin to apply this principle to buildings with some seriousness of purpose. A complete concept of the integration of building systems to achieve environmental economies through complex integration would incorporate the mind-body of the user as an integral part of technology.

Perhaps the most variable of needs are the ones associated with environmental comfort in buildings. And it is these that command most of the energy costs in buildings today. The culprit in warm climates is the rise of a modern technology, by default, namely - refrigerant based air conditioning. Traditional buildings in warm climates evolved to achieve a complex integration of material, structure, thermal modulation, illumination and ventilation through largely fixed and a few changeable elements. Adaptation to seasonal and diurnal variations was the key. Our bodies learnt to adapt to both heat and cold as we grew up through childhood, we changed our clothing and dress codes according to the season, and patterns of activity followed diurnal and seasonal cycles[6]. The buildings were built to dampen and ward off extreme weather conditions and the provision of **closed, semi-open and open-to-sky spaces** with the added variability afforded by the use of screens and shutters over doors and windows provided a built environment for a reasonably comfortable and productive life.

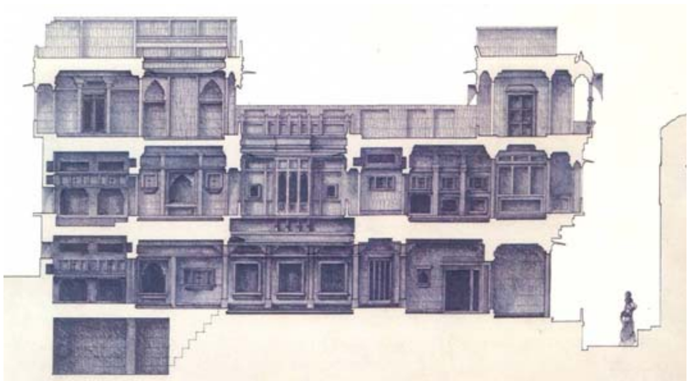


Figure 1

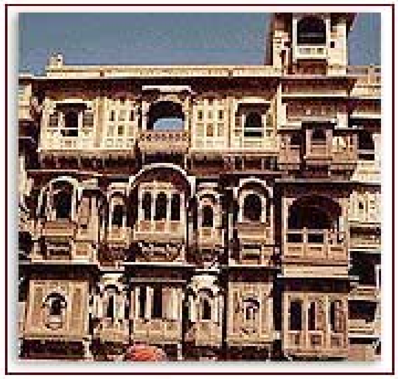


Figure 2

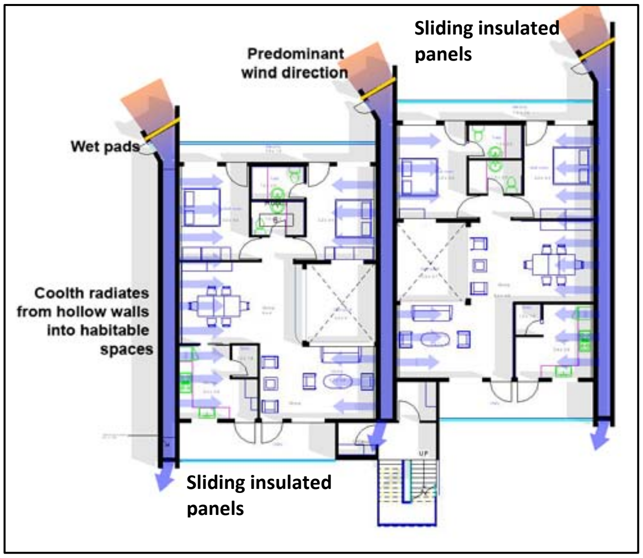
Figures 1 and 2: Sections through traditional Haveli in Rajasthan, Kush Patel

The inhabited built environment here may be conceptualized as a mind-body-tool continuum in which the mind-body is a fairly adaptable organism. The intelligence of these adaptive actions is culturally transmitted behavior that encodes pragmatic knowledge of how to make buildings and how to use them as it evolved over many generations.

As I bring this concept forward into the present I see three significant changes from the old traditional days. First, due to the rapidity of change in ways of building, multi-storeyed thin wall flats with glazed windows as against heavy stone *Havelis*, and the absence of scientific understanding of the thermal properties of new constructions, the cultural transmission of knowledge about the implications of our individual or collective behaviors has broken down. Second, the promise of absolute control over our environment “to world standards by state-of-the-art technology” (air-conditioning and electric lights) has weakened our capacity for adaptation. Third, and this is the saving grace, the science of thermal comfort coupled with cybernetics and communications technologies are waiting for intelligent application. They have the potential to effectively replace the loss of culturally transmitted knowledge and empower each individual to take responsibility for the environmental consequences of the choices being made.

Our recent research shows that integrating passive measures for curtailing the impact of solar radiation on the internal conditions of residential buildings with low energy systems for air movement and ventilation in residential buildings can give reasonable comfort for 90% of the duration of the hottest four months of the year – in Chennai (warm humid climate), Ahmedabad (hot dry climate) and Delhi (composite climate)[7]. The contention is that achieving what I have called ‘aspirational’ comfort is feasible without resorting to conventional air conditioning, provided we respond to our natural capabilities for adaptation and enable simple, and intelligent operation and use of the building by the occupants while integrating calibrated thermal characteristics into the fabric of the building. The model is affordable and requires little energy.

Intelligent operation implies that the use of the building's fans, windows, movable shading devices etc. is instinctive and automatic. To smoothen the mind-body-tool continuum one can integrate simple cybernetic devices such as sensor signals informing the user that "it is cooler outside "so you can open the window, or "no breeze tonight" so you switch on the night-vent fan. Similar devices reading the energy meter can flash green, orange or red, signaling a progressive compounding of the electricity tariff as the rate of consumption rises above threshold of your legitimate share of electric power. You would choose to stay green, intelligently. This model is illustrated in a housing complex design which is presently under development.



Two Bedroom residence - occupants operate these things: windows, outer screens, ceiling fans, forced vent, evaporative cooling.

No air conditioning is provided.

Install your own air conditioner subject to budget metering.

The strategy is to optimize thermal performance using passive technologies first; next – to allow the occupant a range of convenient modulating devices to respond to seasonal and diurnal variations: and finally to provide cybernetic prompts to optimize modulation and to warn against excessive electricity use.

Figure 3: Two Bedroom residence: occupants operate these things windows, outer screens, ceiling fans, forced vent, evaporative cooling.

Homes constitute about 70% of our building stock. Preventing this dominant component of building stock from slipping into the habit of air-conditioning by default is a feasible goal. Achieving this goal is the key to holding down the per capita consumption of energy in buildings to the target mentioned earlier. It will require passive, low-energy systems woven into the structural and spatial configuration of buildings toward achieving mind-body-tool continuum. This brings us to a discussion on the innovation of building materials and systems of assembly.

6 The "DNA" of Building Systems

There are three ancient technologies that serve as archetypes for technical approaches to complex integration in buildings – pottery, textile and the bullock cart.

6.1 "Pottery"

In pottery complex integration occurs at a molecular level. It is the simple and economical process of production that is remarkably versatile in meeting a wide range of functional needs of containers with infinite variations of form and profile and establishing a truly organic mind-body-tool continuum. While this versatility is the remarkable gain of the pottery making process, we sacrifice the potential for alteration and change once the product has been made. And once damaged or worn out it certainly cannot be renewed or repaired to its original condition. The product is lasting but not robust.

6.2 "Textile"

Textiles present another elegant concept of integration in which the weave provides mutual support amongst independent strands to produce continuous flexible membranes. The draping of cloth directly around the body or its conversion through a secondary process of cutting and stitching creates another kind of mind-body-tool continuum. The simple principle of the weave is pregnant with unlimited forms and expressions. The product in this case has an advantage over pottery. It remains amenable to alteration, variation and repair. Once again, a textile cannot renew itself though stitched parts of clothing can be replaced.

New materials science and computerized parametric fabrication are two areas in which the potential of complex integration is being pursued in the technologically advanced parts of the world. These are in the manner of pottery and textile. The functions of structural support, weatherproofing and environmental control with high durability are sought to be combined. This may be a single material or a composite system of several layers. These are in the manner of pottery and textile. The range and versatility, to find a close fit with functional demands and spatial configuration at the time of fabrication is enormous. In cold climates there has been an enchantment with transparency and dematerialization leading to high embodied energy and high cost solutions.

For the technologically less advanced parts of the world, which also happen to be the warm and hot regions, the attempt has been to search low embodied energy solutions utilizing biomass, soil and stone. Shade and opacity take precedence over transparency, Thermal capacity combined with insulation require integration into envelopes and support systems of the building fabric to optimize thermal responses to climate by passive means. We are beginning to see a wide interest in this area of innovation.

The pioneering work of Gernot Minke from Kassel and of Satprem Maini at Auroville in stabilized earth construction with engineering precision is beginning to find broader acceptance. Laurie Baker, working in Kerala, developed arch vocabulary of techniques of using brick work with great efficiency in climatically suitable perforated screens and insulating hollow walls. This has created a mini revolution.

Figure 4

Figure 5

Figures 4 and 5: Economic and appealing brick screens developed by Laurie Baker; Center for Development Studies, Kerala
artlight.blogspot.com

Figure 6: Earthen Construction of Dome: Satprem Main
www.auroville.org

Figure 6: CEB construction: Ashok Lall

Many agro-waste fiber and bamboo based products have been developed as scantlings and boards, but this line is under-explored. Sandwiches with integral vapour barriers and with a range of thermal insulation and surface weathering properties are yet to be worked upon. Similarly the potential of bamboo for long lasting use for structural support in low-rise buildings, as demonstrated by Simon Velez from Bolivia, is just beginning to be taken seriously.

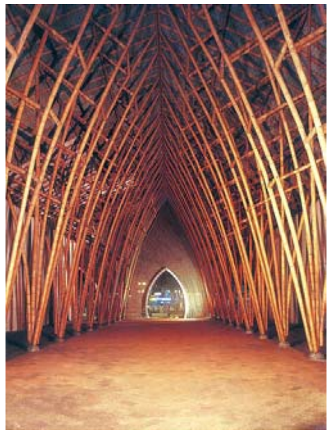


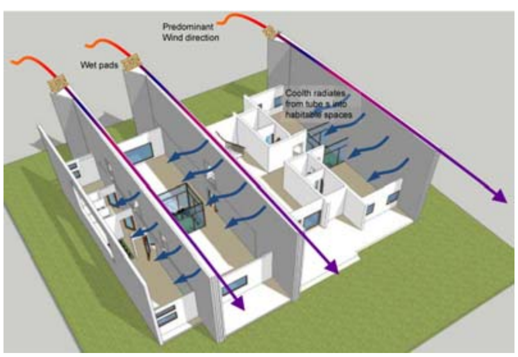
Figure 8: Bamboo Construction: Simon Velez   Figure 9: Bamboo Connection: Shoei Yoh
Images: Arc10studio, Flickr.com

Stone, which is such a plentiful resource, remains the most underdeveloped for construction, whether in structural configurations engineered for greater efficiency in the utilization of material or as exterior veneers in sandwich construction.

In my opinion the route to low embodied energy sustainable construction, that will serve the great majority of the demand for new shelter in urban India, lies in the direction of innovation of new construction products in the three sets identified above. The principle is simple – develop lasting building materials and techniques with natural resources that need little energy to transform them from their natural state for the required performance. This strategy will fulfill the **promise of reducing embodied energy in construction** from present levels.

To return to the idea of woven textile, an interesting parallel in buildings to the idea of weaving is the dynamic interaction between the building fabric with its thermal mass that envelops the habitable space and external heat sink through a fluid medium. The building's supporting structure – its walls and floors - develops annular spaces which improve the moment of inertia of the structural members, making it more stable structurally. These annular spaces circulate cool air or water at night storing the coolth of the night air and the night sky in the mass of the structure. As the structure is also the envelope of the many habitable cells of the building, this coolth is then discharged gradually to the habitable space during the day. Two projects shown below illustrate the principle.

Residential Colony, Bellary



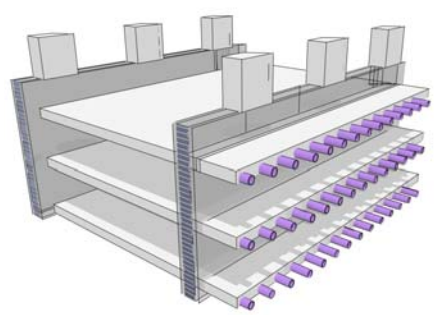


Figure 10: Hollow walls as coolth store   Figure 11: Coolth store in slabs

Structural elements become coolth stores by incorporating annular spaces for air passage interacting with an external heat sink

Development Alternatives, New Dehli

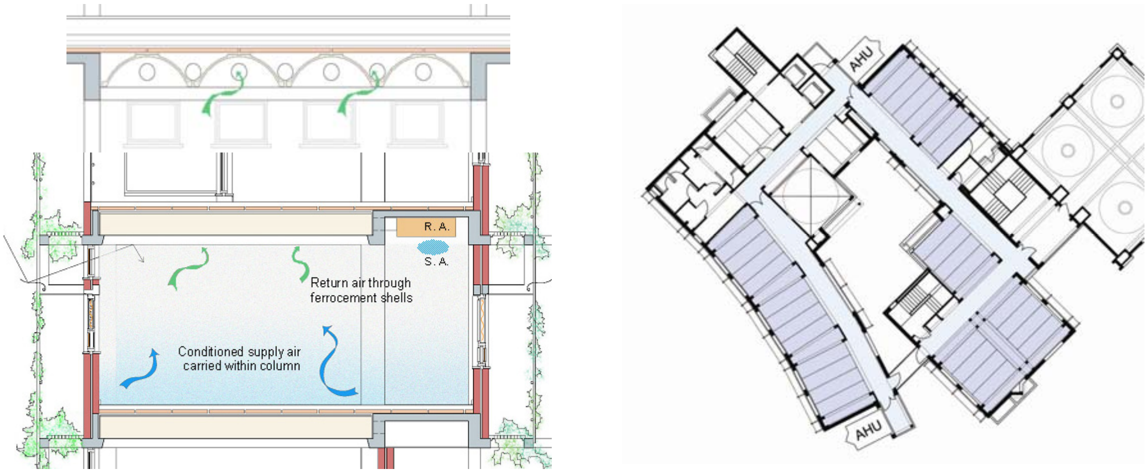


Figure 12: Development Alternatives, New Dehli

Columns and Annular space above ferrocement shells provide the space for air passage. The structural system becomes a coolth store.

6.3 "Bullock Cart"

The bullock cart is an assembly of many components. Here the concept that has evolved as a result of combining divergent functions - holding large loads, providing shelter, mobility- is one of an armature or chassis that supports and connects a number of discrete parts. The DNA of this complex integration is additive, rather than a kind that requires fusion (pottery) or interlocking (textile). The additive nature of the DNA makes the total organism robust – it is amenable to repair, alteration and improvement. It can renew itself by cyclic replacement of parts that age at varying rates and can take advantage of small but valuable innovations for upgrading performance. Building designers know this nature of buildings in their bones and building trades today are largely organized according to this DNA.

John Habraken[8] in his theory of **Supports** clarified the DNA's mission: to re-establish a mind-body-tool continuum in industrialized systems of building. The principle of responsiveness to varying needs and changing circumstances expounded here warns against the dangers of enforcing immutable integrated systems, whether of the "pottery" kind or of the "textile" variety. This is particularly significant when considering housing and other building types with variable user interaction and the desire for up-gradation and renewal as affordability improves over time. The system of Supports also enables an incremental approach to affordability, enabling a movement forward with the "next (affordable) practice" as against an insistence on "best (unaffordable) practice". There is another important advantage – it opens opportunities for small and medium sized local enterprise to participate in the economic cycle of building. This economic attribute of a way of building, which is recognized by the Target Issues for Sustainable Construction of the Holcim Foundation, takes us to the next "viewing lens".

7 Socio-Economics of Innovation

This is the heart of a strategy for innovation in construction. I am reminded of Dr. Muhammad Yunus's address at the first Holcim Forum. This was the first time that the theoretical framework for sustainable construction identified social equity and economic performance as target issues integral to sustainable construction. The lesson of the success of his Grameen Bank[9] experiment was that it is a bottom up process of democratizing wealth generation. The beauty of micro-finance is that the financial product is accessible to the most needy with the least assets. So it is with technological innovation. The reinvention of construction is required to be seen as a process that distributes wealth as it generates it.

A prerequisite for such a process is access to knowledge. When knowledge is universally accessible, then innovation occurs without access to large capital and with test laboratories in the field. The nature of these innovations is evolutionary in that they are responsive to felt needs, are incremental and do not destroy or destabilize existing social structures. Equally, though, there is the role of the frontier technologies which are constructed on top of an elaborate platform of a wide array of existing technologies. Being inherently capital intensive with long gestation periods they rely on immense scale for their economic viability. These sometimes displace and destabilize existing social structures as they begin to determine social preferences rather than serve the real needs of society. The curtain glazing industry's aggressive marketing and success – despite disastrous consequences, is a case in point. The same can be said for refrigerant based air conditioning which is today's default solution to thermal comfort.

E.F. Schumacher in his book "Small is Beautiful: Economics as if People Mattered"[10]introduced the thesis of technological development whose objective is to distribute wealth and to promote grace and dignity as social values as against consumptive servitude parading as "choice". He coined the term **"intermediate technology"** for production systems that would be built up from a platform of local resources using simple machinery requiring little capital investments - the Grameen Bank principle applied to industrial production.

Between these two extremes that I have portrayed there lies a whole spectrum of the socio-economics of innovation. This is summed up in the illustrative diagram below.

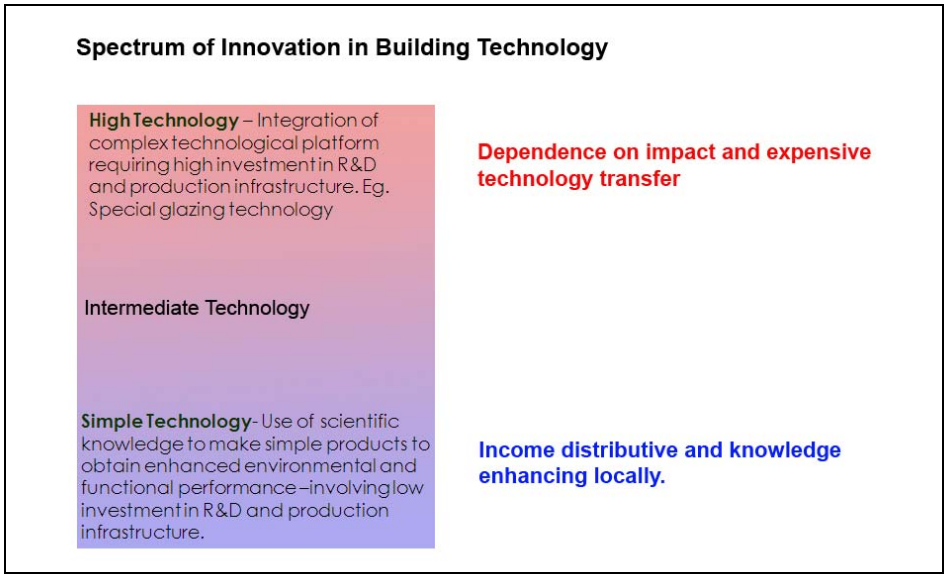
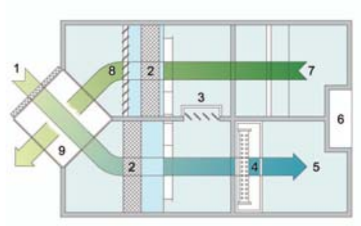


Figure 15: Spectrum of Innovation in Building Technology

My purpose here is twofold. First, I want to emphasise that innovation is possible, valid and beneficial at all locations across the spectrum. Second, I want to suggest that for developing societies the strategy for innovation in building technologies toward sustainability must lie generally in the "cool" zone of the spectrum. What is needed is collaboration of the latest technical and scientific knowledge available in the world with the innovation instinct of that "field technologist" who is one with the needs and aspirations of society and is conversant with the reality of resources that are readily available, and the affordability of his market.

The innovative modes of production would be based largely on the intermediate technology model propounded by Schumacher – requiring modest investment with economic viability at scales of production that service local or regional demand, modest investment per unit of employment created, and a quicker and shorter loop for the generation and distribution of wealth. It is my belief that practically all environmental performance criteria that would be applicable to building fabric to make it sustainable can be met through such processes of innovation.



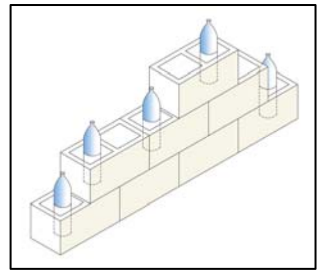


Figure 16: Photovoltaics from human hair Milan Karki, Nepal

Figure 17: Hybrid Eva p-Cooler New Dehli

Figure 18: High thermal capacity wall

By and large it is in the electro-mechanical systems of buildings, particularly those which require computerized automation, and hi-tech wonder materials, that we encounter high costs of innovation, production and certification, and an even higher price in the marketplace due to the burden of marketing. This is the "hot" zone of the spectrum. Such products need economies of scale and widely distributed markets. The strategic principle for the "hot" zone innovators would be to seek the highest common factor of demand in a abroad section of society – in the emerging economies this section is the growing middle class. (Intelligent high performance window, thermal mass management water pumps, phase change body cooling wear, cool walls and slabs coupled with comfort air movement fans, variable thermal property walls and ceilings)

Then, I would commend the "bullock cart" model of conceptualizing buildings, whether they are simple and small or complex and large. The robustness of a building assembly, whose DNA is that of an organism in continual regeneration, responding to new requirements and new opportunities, is a key to sustainable construction. We look at two projects which attempt to exemplify a comprehensive strategy for our "play with complexity".

7.1 System for Affordable Housing

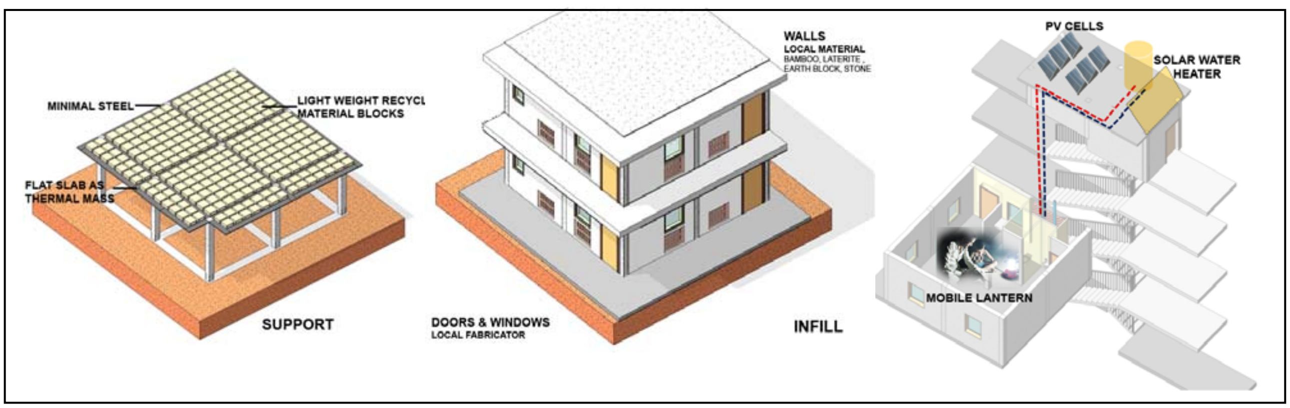


Figure 19: Systems for affordable housing

Figure 20: Adapted housing

Affordable housing requires a high-quality long-life robust 'support' system. The external climate modifying transition zone and be filled in to respond to local climate and orientation- shade screens, quilted panels, sun spaces, vegetables beds and vines. Infill and envelope will be according to local practice and affordability. The system will upgrade and regenerate over decades. Low-cost-Hi-Tech photovoltaics and solar water-heating are integrated to minimize dependence on grid electricity

7.2 Institutional Complex for the Presidential Estate, New Delhi

Figure 21: Project Proposal

The project was proposed by President Abdul Kalam.

A 12x12M grid of columns rising from the underground car park supports the buildings and a pergola carries P.V. arrays generating 3.5 MW of Electricity.

Figure 22: Support system

The 'support' system combines structure with shade below and energy from the intercepted sunlight above. The excavated soil is used for earth block masonry and roof gardens.

The buildings combine local materials and construction to achieve high environmental performance.

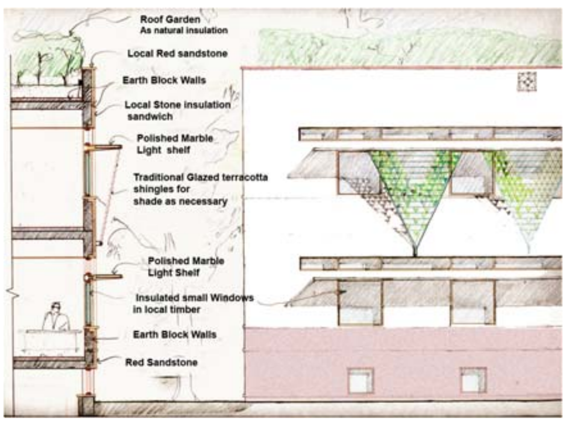


Figure 23: Prototype

The system is an integrated micro-climate – a prototype for public buildings

8 Conclusion

If these societies, who are now characterized as "emergent" economies, are intelligent and wise, qualities that I believe are innate in them and must be invoked, they have the potential of evolving sustainable lifestyles of dignity and grace where "nothing is lacking". This evolution does not have to go through the cycle of addiction to consumption followed compulsorily by withdrawal pains when the drug becomes scarce. In this realization we are indeed fortunate and blessed. We could construct a relatively simple, yet a healthy and enriching life that is sustainable. This can be achieved through an appropriate strategy for innovation:

- Follow Supports (Habraken) in configuring buildings
- Follow "Small is Beautiful" (Schumacher) in launching wealth distributive systems of production
- Focus science and engineering on intermediate technology for low embodied energy materials and components
- Deepen the science of passive design for thermal comfort integrating thermal properties with structure and envelope – avoid/delay the need for air conditioning
- Do low-cost-hi-tech - for solar electricity and for cybernetics
- Make buildings and their operable parts symbiotic extensions of the mind-body

Aren't they all truisms!

Notes

[1]This is the title of an M.A. course at the Department of Built Environment of the London Metropolitan University, which is devoted to developing professional skills for working with poor communities. The course was initiated by Maurice Mitchell.

[2]India's urban population has doubled from 109 million to 218 million during the last two decades and is estimated to reach 300 million by 2000 AD. As a consequence cities are facing the problem of expanding urban slums. Population Growths Trends, Projections, Challenges and Opportunities - Planning Commission India 2005

[3]Construction activity being labour intensive has generated employment for about 33 million people in the country. ndianconstructionindustry.com/2007-2009

[4] Indian Construction Industry Directory According to a study by ASSOCHAM, the burgeoning Indian construction industry, currently worth $70 billion, will rise to US$120 billion by 2010. www.indianconstructionindustry.com/2007-2009

[5]Ashok Lall Evolving Traditional Practices for Sustainable Construction in the Present. I: INTBAU International Conference; 11 – 14 Jan. 2007, New Delhi, India.

[6]J. Fergus Nicol and Michael A. Humphreys.2000, Adaptive Thermal Cofort and Sustainable Thermal Standards for buildings.

[7]Ashok B. Lall, Ruchi Parakh. Preventive Strategy for Air Conditioning – A Case for India. In: Proceedings of Conference: Air Conditioning and the Low Carbon Cooling Challenge, Cumberland Lodge, Windsor, UK, 27-29 July 2008. London: Network for Comfort and Energy Use in Buildings, http://nceub.org.uk.

[8]Habraken, N.John. Supports: an Alternative to Mass Housing. The Architectural Press, 1972.

[9]Grameen Bank: A micro credit bank in Bangladesh set up by Dr. Muhammad Yunus in 1983, gives small loans to poor women without collateral. It is the largest bank in Bangladesh. 90% of its ownership is with the borrowers themselves.

[10]E.F. Schumacher. Small is Beautiful: Economics as if People Mattered. ISBN 0-88 179-169 9-5, 1973.