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Nanotechnology – The Rising Horizon

P. Datta & Shankar Dutta

The emerging area of nanotechnology is expected to be the frontal area of research for the next two decades. This research is likely to revolutionize technology in ways that will enable humankind to manipulate even individual atoms so as to produce the desired effect. This paper looks at nanotechnology and its implications for areas like health, environment and defence.

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'Micron' scale technology realized in MEMS (Micro Electro Mechanical System) is gradually culminating in 'Nanotechnology' reveling in dimensions of atoms and molecules. The credit for this goes to Richard P Feynman (Nobel Prize winner in Physics), when he made the observation, "There's plenty of room at the bottom".

"The principles of Physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big," said Feynman.

In the area of miniaturization, Feynman prophesised the possibility of greatly increasing computing power. His approach was based on scaling (down). He asked why one could not write the entire 24 volumes of Encyclopaedia Britannica on the top of a pin.

To do this one needs the ability to manipulate matter at the atomic scale. This bears promise to produce a device of unprecedented speed and efficiency. The emerging area, called nanoscience and nanotechnology, is expected to be the frontal area of research for the next two decades. The outcome of this research is likely to revolutionize technology in ways that will enable humankind to manipulate even individual atoms so as to produce desired effects.

Eric Drexler is another visionary whom many would call the "Father of Nanotechnology". His vision was first outlined in his book 'Engine of Creation, The Coming Era of Nanotechnology', the first few paragraphs of which are deeply insightful:

"Coal and diamonds, sand and computer chips, cancer and healthy tissue: throughout the history, variations in the arrangement of atoms have distinguished the cheap from the cherished, the diseased from healthy. Arrange one way, atoms make up soil, air and water; arrange another, they make up ripe strawberries.

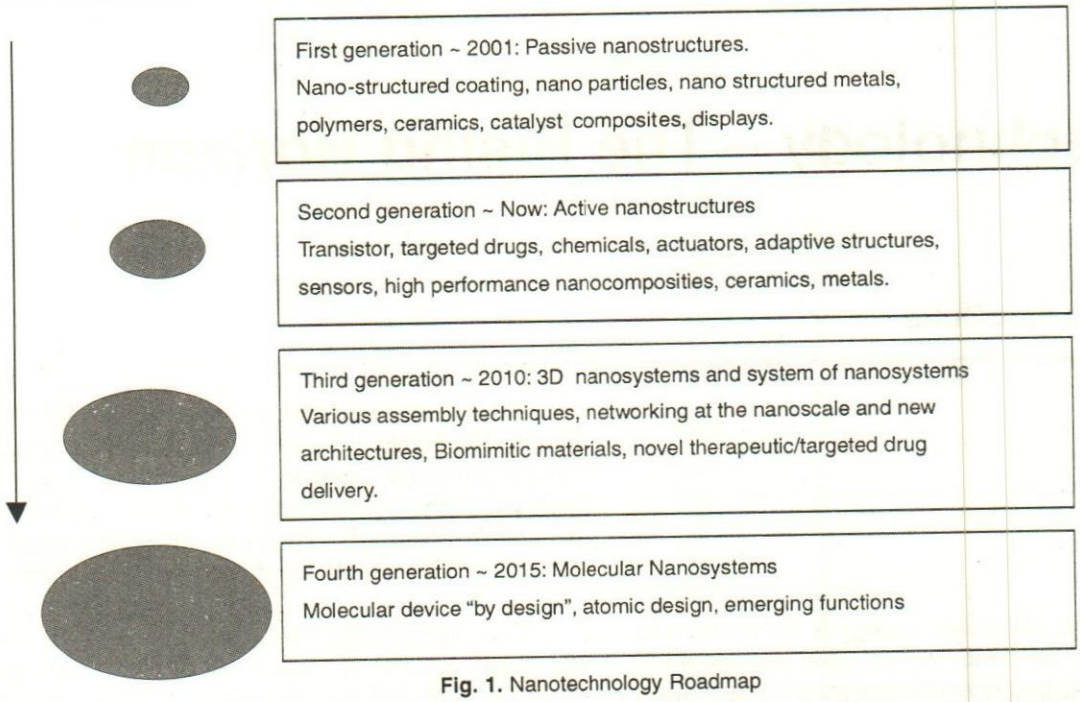

Fig. 1. Nanotechnology Roadmap

Arranged one way, they make up homes and fresh air; arranged another, they make up ash and smoke.

Our ability to arrange atoms lies at the foundation of technology. We have come far in our atom arranging, from chipping flint for arrowheads to machining aluminum for spaceships. We take pride in our technology, with life saving drugs and desktop computers.

Yet our spacecrafts are still crude, our computers are still stupid and molecules in our tissues still slide into disorder, first destroying health, then life itself. For all our advances in arranging atoms we still use primitive methods. With our present technology, we are still forced to handle atoms in unruly herds.

But the laws of nature leave plenty of room for progress and the pressures of the world competition are even now pushing us forward. For better or for worse, the greatest technological breakthrough in history is still to come."

Nanotechnology is science and engineering of the 21st century and we have two different approaches to achieve Nanotechnology. One is the 'top down' method that miniaturizes devices and systems to the scale of a nanometer. This is similar to the conventional MEMS. The other method is the 'bottom up' in which atoms and molecules are integrated to form devices shaping the system atom by atom. Both methods are important for future science and technology. In the long term, there will be a convergence of nanotechnology, biotechnology, information technology and cognitive technology. This convergence is already progressing and will result in the development of novel nanoscale materials and devices. Figure 1 represents the present and future scenario of nanotechnology [Source: External Review Draft, Dec. 2005, US Environmental Protection Agency].

Nano Materials

The unique properties of various types of articulately produced nanomaterials give them features like exceptionally strong, hard, ductile at high temperature; wear resistant, erosion resistant and chemically very active. These novel properties are highly desirable for the applications in commercial, medical, military and environmental sectors.

There are many types of intentionally produced nanomaterials. For the purpose of this article, nano-materials are organized into two types: Carbon-based materials and Nanocomposite.

Carbon-based materials – CNT (Carbon Nano Tube)

These nano-particles are made entirely of carbon, taking the form of a hollow sphere or tube. Out of these, CNTs have attracted huge academic and industrial interests due to its remarkable electrical and mechanical properties. The carbon-carbon bonding in CNT is sp^2 as in graphite. The tubes can therefore be considered as rolled-up graphene sheets.

CNT has amazing mechanical properties. The Young's modulus can be as high as 1000GPa, which is five times higher than steel; the tensile strength can be up-to 63GPa, around 50 times higher than steel. Moreover, CNTs are among the stiffest and strongest known material.

These properties, coupled with its lightness, gives CNTs great potential in applications such as aerospace, flat panel displays and scanning probe microscope. The unique properties of CNT will lead to many more applications. Figure 2 shows a single-walled carbon nanotube grown using e-beam lithography.

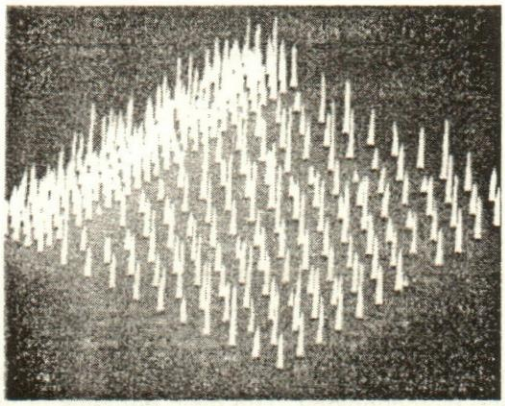

Fig. 2. Single nanotubes were grown using e-beam lithography

Source: Nano Lab

Nanocomposite

The definition of Nanocomposite has broadened significantly to encompass a large variety of systems – one dimensional, two dimensional, three dimensional and amorphous materials – made of distinct components and mixed at nanometer scale. The general class of nanocomposities, organic/inorganic materials, is a fast growing area of research. Its material properties not only depend upon the properties of individual parent but also on their morphology and interfacial characteristics.

The rapidly growing field is generating many exciting new materials with novel properties. Already, nanocomposities, such as nano-sized clays, are being added to products ranging from auto parts to packaging materials. Other examples of nanocomposites are: zeolites, metal oxide (e.g. Titanium Oxide), metal phosphates, chacogenides etc.

Nanocomposites promise new applications in many fields like light weight components, nono-linear optics, nano wires, sensors, to name a few. Figure 3 shows ZnO nanowires developed by Nano Lab.

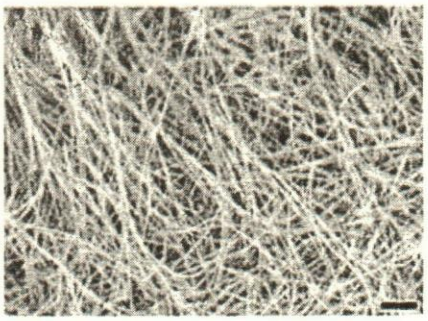

Fig. 3. ZnO Nano-wires

Source: Nano Lab

Potential of Nanotechnology

As applications of Nanotechnology developed over time, it has the potential to help mankind in a very broad way and at the same time it shrinks the human footprint on the environment. This is important, because over the next 50 years the world's population is expected to grow 50%, global economic activity is expected to grow 500%, and global energy and material use is expected to grow 300% [World Resources Institute, 2000].

Environmental Benefits

Nanotechnology may be able to give advance environmental protection by addressing the long-term sustainability of resources like water, energy and remediation.

Water

Nanotechnology has the scope to contribute to long-term quality, availability and viability of water resources. Through advanced Nanotechnology-based filtration one can enable more water reuse, recycling and desalinization. For example, Nanotechnology-based advanced Flow Through Capacitor (FTC) desalts sea water using one-tenth the energy of the state of the art reverse osmosis and one hundredth of the energy of distillation systems [Nanotechnology Draft White Paper, Dec 2005, US EPA].

Energy

Nanotechnology has the potential to contribute to the reduction in energy demand through lighter materials for vehicles, materials and geometries that contribute to move effective temperature control, more improved manufacturing process, low loss electrical materials and components. Power transmission could be improved by using CNT that provide better conduction of large quantities of high voltage electricity than copper wire, at one sixth weight.

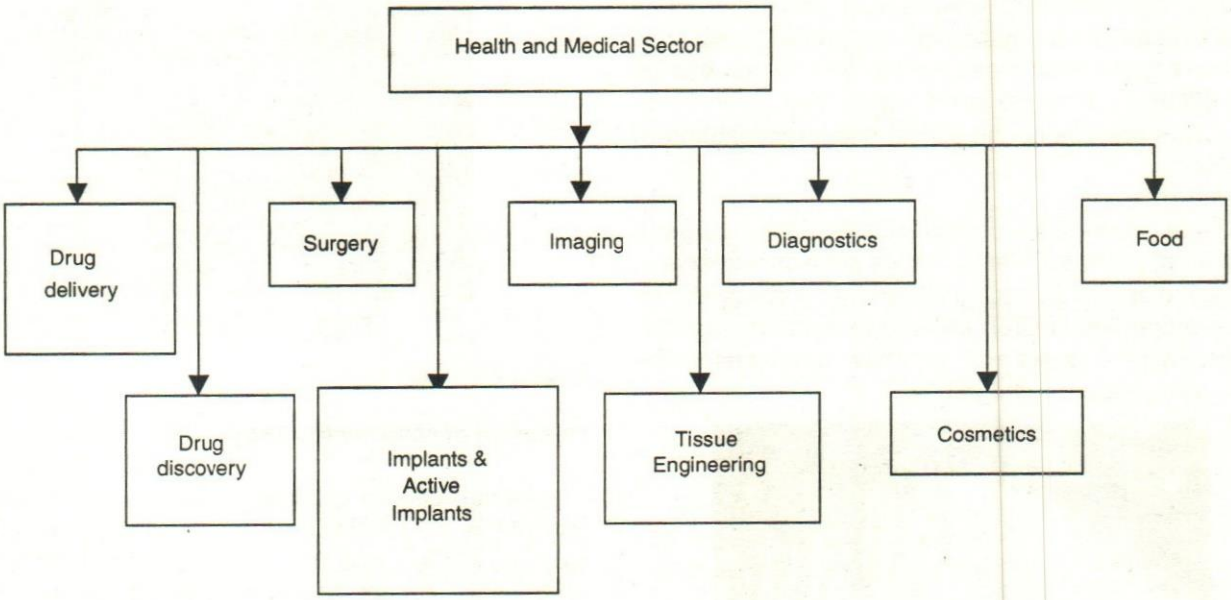

Fig. 4

In addition to increasing the efficiency, it also can contribute to alternative cleaner energies. For example, a new type of highly efficient photovoltaic cells was demonstrated recently that consists of quantum dots connected by CNT [Source: NREL]. Further, multi-walled CNTs may increase the performance of hydrogen fuel cells, which can drive the automobile industries in future.

Remediation

Environmental remediation includes the degradation, sequestration or other approaches that result in reduced risks to human and environment due to chemical and radiological contaminants.

Chloro-organics are a major class of contaminants in water in these days. Nano-scale zero valent iron treats aqueous dissolved chlorinated solvents in-situ and also may remediate the dense non-aqueous phase liquid sources of these contaminants within aquifers.

Nano particles such as poly dendrimers can be used for enhanced filtration of metal ions like Cu^{++}, Ag^{+}, Fe^{+++}, by attaching functional groups like amines, carboxylates. Other materials like Titanium oxide-based nanomaterials have been developed for potential use in the photo-catalytic degradation of various chlorinated compounds. Silica-titania nanocomposites can remove elemental mercury from vapours such as those coming from combustion sources.

Nanotechnology in Medical and Health Sector in 2015

The domain of medical and health is influenced by the 'nano-biotechnology'. The main domains of application of nanomaterials that can be identified in this sector are:

The details in this tree (Fig. 4) are ordered randomly. In each domain of application different products can be identified in which nanomaterials play an important role at present or have the potential to play in the future.

Nano particles can be used to deliver drugs effectively on the right spot in the body, just at the diseased site. Therefore, lower doses will be required and the patient will encounter less side effects. Nanobiotix (a French company) develops nanoparticles (consists of nucleus of iron oxide and an antibody), that can recognize cancer cells, pass through the membranes and destroy them.

Another area of application with very high expectations is the imaging of cells. Nanoparticles (such as Au, Fe, F, Mn, quantum dots) could be extremely important for the development of contrast agents for almost all imaging techniques (MRI, Ultrasound, Optical, Nuclear).

The research for the cosmetic sector is related to health and medical sector and hence much research is done in the nanomaterials field. A very large number of applied and granted patents based on the design and processing of nanomaterials are related to this cosmetic

sector. Nanocrystalline based sun blocker (protection) cream that possess zinc-oxide nanoparticles offers best protection against both sunburn and skin cancer.

Nanotechnology and Defence

The exploration of Nanotechnology will create new defence-related innovations, which are likely to have applications in the civilian sector as well. In coming years defence R&D is likely to become an increasing source of support for the nano community in India.

Microchip-sized sensors to detect chemical and biological threats will be integrated into clothing, which will reduce the need carry bulky sensor equipment. Light weight, non-bulky materials that protect the torso and extremities against bullets, shrapnel and blast wave are a major target. Combining that with Nanotechnology innovations in hazardous agents neutralization, drug delivery and actuation of breathable – sealable fabrics can create a complete chem/bio sensing and protection system that operates automatically through a 'smart battle-suit' ('Nanotechnology and its Impact on Industry', Massachusetts Technology Collaborative.)

As the Japan metro attack has shown, terrorist groups can any time have access to chemical warfare agents. The only way of fighting such form of terrorism is to detect the outbreak of such an event at the onset. Research so far has shown that carbon nanotube could be used as extremely sensitive chemical sensors, particularly for chemical warfare agents, offering several advantages in terms of a large active area due to high aspect ratio, sensitivity and miniaturization compared to conventional devices.

Nanotechnology and the IC Industry

Nanotechnology is steadily making inroads in the semiconductor IC industry. Nanotubes and self-aligned polymers are being looked upon as potential nanomaterials for the IC industry. However, technology needs to evolve to realize practical devices and circuits. Advanced characterization tools like Atomic Force Microscope (AFM), High Resolution Scanning Electron Microscope (SEM) and Focused Ion Beam (FIB), are helping the technological development by exploring material in atomic and molecular dimensions. FIB is capable of building nano-scale templates and structures for device applications. AFM has benefited by Nanotechnology since it can use nano-tubes as tips for finer measurements. In the pursuit of device structures, chemical vapour deposition (CVD) is going to play a vital role in selective growth of materials in nano-scale. Nano-lithography is taking shape using self-assembled polymers.

One needs to look forward beyond megasonic cleaning in nano-fabrication. Supercritical fluids with low viscosity and negligible surface tension are being explored to clean such low dimensional structures and nanotubes with high aspect ratio. Nanotubes with ballistic transport properties are likely to be used as interconnects in the nano-circuits.

The future of nanotechnology

Let us imagine a *'Fantastic Voyage'* like nanotechnology driven tiny robotic submarines navigating our blood stream, reaching our heart or brain, and facilitating operations in the affected portions. This will be the kind of potential that nanotechnology can create in the medical and health sectors. Applications will extend even more broadly to ecological health. More targeted fertilizers and pesticides that result in less agricultural and lawn/garden runoff of nitrogen, phosphorous and toxic substances will be an emerging application of nanotechnology.

Sensing its vast potential the US and other countries have already started flowing a huge amount of money into the field of nanotechnology. India too has started R&D work in this direction. There are estimates that the global sales of nanomaterials could be well above $1 trillion by 2015 (M C Roco).

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Nanotechnology & MEMS: Enabling Technologies

Lalit M. Bharadwaj

Nanotechnology is a field which deals with materials and systems with at least one dimension in the range of 1-100 nanometer, while Micro Electromechanical Systems (MEMS) include all those devices that have dimensions in microns. This paper explores the unlimited opportunities that nanotechnology has opened up for fundamental and applied research and innovative high performance miniaturized product development for all sectors of the economy, including the spheres of health and pollution control.

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Nanotechnology is a field which deals with materials and systems with at least one dimension in the range of 1-100 nanometer (1 nanometer is 10^{-9} metre, and the diameter of the human hair is about 70,000 nanometers). Micro Electromechanical Systems (MEMS) include all those devices that have dimensions in microns, and have both electronic and mechanical components together. Nanosystems are fabricated using the processes which have fundamental control over the physical and chemical attributes of atoms or molecules, mainly using the self assembly processes, while MEMS are fabricated in the same way as semi-conductor devises using lithography techniques.

Nanotechnology and MEMS, are new enabling technologies for the development of devices, system, components and materials for every sector of the industry, and it is predicted that this century will be dominated by industrial revolution through hybrid devices based on MEMS and Nanotechnology. BioMEMS and BioNanotechnology take advantage of innumerable molecular and nano devices working in all living systems and have been perfected over billions of years. These devices can be interfaced with available micro and nanostructures to design and develop commercially viable products with higher performance and selectivity. For development of specific devices, the core expertise required is in the domain of interfacing functional and intelligent biomolecules with active surfaces including characterization, for their wide ranging applications in healthcare, agriculture, defence, material science, etc.

The market for these technologies is growing very fast and with the development of new materials and devices, the nanotechnology market has already crossed the US $ 100 billion mark, and for MEMS this figure is at US $12 billion. According to James Murday and Mike Roro National Nanotech Initiative, the nanotechnology market is expected to touch US $1 trillion by 2015 out of

which materials, electronics and pharmaceuticals will account for 70% of the total market. Some of the areas of active research are novel foods, medical devices, chemical coatings, personal health testing kits, sensors for security systems, water purification units, manned space craft, displays for hand-held computer games and high-resolution screens. In US there are more than 400 companies in business in these areas and majority of these are start-up companies. Europe and Japan are lagging behind but are putting in all efforts to increase their share in the world market. Thus MEMS and nanotechnology have opened unlimited opportunities for fundamental and applied research and innovative high performance miniaturized product development for all sectors of the economy.

The technological revolution during the last half century was dominated and driven by unprecedented progress and growth in semiconductor devices. The semiconductor devices are approaching their limit in terms of miniaturization and performance. Thus, it is obvious to look for entirely new concepts for developing miniaturized devices with higher precision, performance and reliability through nanotechnology.

Nanotechnology is the fastest growing sector of science and technology and developed/developing countries are investing heavily in terms of manpower, infrastructure and funding to take maximum economic advantage of this most lucrative enabling technology, for maintaining their global superiority. Nanotechnology is going to have an impact on all aspects of human life. The constant search for better products and processes is spreading the application of nanotechnology across various industries. Although the chemicals and materials market was the first to adopt nanotechnology, the focus now seems to have shifted to the healthcare and biotech sector. Much of the miniaturization of computer chips to date has involved nano-science, and it is expected that products for industry applications and defence and security applications are likely to be the first to enter the marketplace in the healthcare and biotech sector. Research is driven by the need to improve medical equipment, to find better drug delivery systems, and by the search for medical cures. Overall, the promise of a better quality of life and the potential for lucrative returns are ensuring heavy investments and innovation in this relatively new technology.

The present focus is on long-term research on the manipulation of matter at the atomic and molecular levels, giving an unprecedented ability to create building blocks for advanced products such as new classes of devices as small as molecules and machines as small as human cells. This research could lead to continued improvement in electronics for information technology; higher performance, lower maintenance materials for manufacturing, defence, transportation, space and environmental applications; and accelerated, biotechnical applications in medicine, health care, and agriculture.

Priority areas are: (1) research to enable the nanoscale as the most efficient manufacturing domain; (2) innovative nanotechnology solutions to biological-chemical-radiological-explosive detection and protection; (3) development of instrumentation and standards; (4) the education and training of the new generation or workers for the future industries; and (5) partnerships to enhance industrial participation in the nanotechnology revolution. The convergence of nanotechnology with information technology, modern biology and social sciences, will reinvigorate discoveries and innovation in almost all areas of the economy.

Nanotechnology has the potential to make substantial improvements in the general quality of life and is, therefore, drawing the attention of entrepreneurs and investors around the globe. Recent product launches, such as transparent sun blocks, stain-free fabrics, golf balls designed to fly straight, and nick-proof trims on hummers, clearly demonstrate the enormous potential of the technology to provide superior medical treatments, better production processes, faster computers and smaller memory devices.

With many more nanotech-based products presently in their developmental stage and expected to be launched within the next few years, the nanotechnology industry is currently in the late introduction or early growth phase and, hence, faces numerous challenges. An added challenge for nanotechnology companies is the lack of sufficient consumer knowledge concerning the benefits offered by nanotechnology, as well as the complex nature of such products. "Initially, nanotechnology products are expected to be more expensive than traditional products," notes the analyst of this research. "Convincing the customer that the added value is worth the additional cost will be key determinant of the growth of this technology."

The constant search for better products and processes is spreading the application of nanotechnology across various industries. In the healthcare and biotech sector, research is driven by the need to improve medical equipment, to find better drug delivery systems, and by the search for medical cures. Overall, the promise of a better quality of life and the potential for lucrative returns, are ensuring heavy investments and innovation in this relatively new technology.

The nanotechnology industry can be compared to the stage of the information technology (IT) industry in the early to mid-1990s. While the sector holds high potential for future growth, its present stage is characterized by numerous small market participants, lack of clarity about the final product, absence of clearly defined structure, low profit margins, and high research and operational expenses.

"Although the chemicals and materials market was the first to adopt nanotechnology, the focus now seems to have shifted to the healthcare and biotech sector," says the analyst. "Much of the miniaturization of computer chips to date has involved nanoscience, and it is expected that products for industry applications and defence and security applications are likely to be the first to enter the marketplace."

While nanotechnology is still generating considerable excitement among scientists, businesses, and governments around the world, some in the environmental movement have been quick to point out the potential dangers of nanotechnology, either real or perceived. This has been portrayed in popular newspapers and has led to a lot of confusion, largely based on a lack of understanding of the difference between present-day nanotechnology and the futuristic ideas of molecular manufacturing and self-replicating nanobots.

A growing band are excited by nanotechnology's ability to mimic nature, in designing highly energy-efficient systems that operate precisely and without waste-fix only that which needs fixing, do only that which needs doing, and no more. Here are some possibilities:

- Improved health through better diagnostics and new treatments, or even cures, for a variety of diseases and ailments, from diabetes to cancer, and from AIDS to blindness
- The reduction of emissions of pollution and greenhouse gases through improvements in energy efficiency, renewable energy technologies, and lighter and stronger materials for automobiles and aircraft
- Enhanced abilities to detect environmental contamination and predict adverse environmental consequences of new materials or chemicals, as well as new environmental remediation technologies
- Raising the standard of living of the world's poor, most notably through the possibility of cheap, clean and local generation of electricity. New materials and processes are already dramatically improving the efficiency, and lowering the cost, of solar power generation.

Though nanotechnology is a highly interdisciplinary domain of science and technology where all disciplines converge, it can be broadly classified into two sectors depending upon the mode of realisation of technology and application:

- Nanoelectronics
- Nanomaterials
- Nano-Biotechnology

Nanoelectronics deals with the miniaturization of present submicron semiconductor technology with feature size below 100 nm. Nanomaterials take advantage of entirely different chemical, physical, optical and electronic properties of nano-particles than bulk material. Nano-biotechnology deals with interfacing functional biomolecules with available devices for development of devices with higher performance in terms of selectivity, sensitivity and economics.

The emerging fields of nanoscale science, engineering, and technology - the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new properties and functions - are leading to unprecedented understanding and control over the basic building blocks and properties of all natural and man-made things. The convergence of nanotechnology with information technology, modern biology and social sciences will reinvigorate discoveries and innovation in almost all areas of the economy. The long-term research on the manipulation of matter at the atomic and molecular levels will give an unprecedented ability to create building blocks for advanced products such as new classes of devices as small as molecules and machines as small as human cells.

Nanomaterials

Nanomaterials (nanocrystalline materials) are materials possessing grain sizes on the order of a billionth of a meter. They manifest extremely fascinating and useful properties, which can be exploited for a variety of structural and non-structural applications. The unique properties of nanomaterials and structures on the nanometer scale have aroused the attention of materials developers. Nanomaterials are already in the market in some specific applications for product performance improvement, for example, as fillers in plastics, as coatings on surfaces, and as UV-protectants in cosmetics. The technology holds more promise for the future and is expected to bring more disruptive changes to both

products and markets in the area of medicine, plastics, energy, electronics, space, etc. Nanomaterials are synthesis by sol-gel, inert gas condensation, mechanical alloying or high-energy ball milling, plasma, epitaxial growth, laser ablation, electro-deposition, etc.

Driven by what is already high demand for nanotechnology research and development, it is expected to see a trend towards increased industry acceptance and large-scale availability of raw nanomaterials. Today a large portion of the work being done in nanomaterials is yielding fascinating results that just don't yet meet the rigors of large-scale commercialization. Invention of a great product is only the first hurdle: advancements in scalability, reliability and affordability are also necessary.

Nanoparticles are also produced as agricultural byproducts: airborne dust and aqueous runoff that cause air and water pollution. Controlling these nanoparticles is in the best interests of efficieny, cost-effectiveness and environmentally responsible agriculture. Soils are aggregates of nanoparticles, layered particles, organisms and water. The environmental impact (biodegradability) of agricultural byproducts in soils needs further research. Viewing soil as a nanocomposite, and applying the paradigms and technologies of nanoscale science to it, can lead to more efficient and environmentally-friendly agriculture.

Bionanotechnology

Nature has created a large variety of molecular devices which are working in the living system, ranging from microorganisms to human beings. Nature creates these devices by self-assembly process and does not require billions of dollars of lithography-based fabrication facilities used in VLSI devices. The life processes and materials have been perfected by nature over millions of years. These devices will find applications in electronics, life sciences, medicine, space, defence, bio-warfare, security, etc. Thus, the best way is to directly utilize a large number of molecular devices working in the living systems for engineering applications by interfacing with non-biological materials and devices. These hybrid devices will have higher performance and perfection as molecular devices, such as, DNA, biomolecular motors, proteins, enzymes have well established dedicated functions to perform under a given set of environmental conditions.

At the same time, these molecular devices can be isolated from the living system or synthesized in a simple molecular biology laboratory without huge investments required for the semiconductor industry. The system that works inside our bodies, in our cells, and in nature that surrounds us is full of examples of nanoscale systems. Whether it is our genetic makeup that works for storing and transferring of information about our looks, personality or susceptibility to diseases or increased understanding of the calcium carbonite nanostructures used in seashell construction, nanotechnology holds massive potential for the healthcare and life sciences market.

Nanodevices enable drug delivery mechanisms that can send biologically active materials directly to the location where they are beneficial and reduce side effects to make pharmaceuticals more effective. Some important healthcare areas are self-assembly, biointerface, implants, nano-robots and tissue engineering. Nucleic acid diagnostics/molecular diagnostic assays, point-of-care testing, genomics, proteomics, DNA biochips, and microarrays, regenerative medicine, the healthcare environment, drug discovery tools, liquid handling, separation and filtration, nanopore sequencing and separations etc.

Bionanotechnology will bring new kind of sensors for applications in biology and engineering based on nanoparticle tagging, nanotube and nanowire, quantum dots, piezoelectric acoustic assays/rupture event scanning, enzymatic electrochemical detection, single-molecule sequencing and analysis, lab-on-a-tape, nanoarrays, dip pen nanolithography, nano mass spectrometry, nanogrid etc. These devices will play an important role in early warning and treating life-threatening conditions, including cancer and heart disease in the form of body implants to deliver smart drugs or carry new cells to repair damaged tissue.

Bionanotechnology provides new tools/sensors for agriculture for improving the efficiency of crop production, food processing, food safety and environmental consequences, storage and distribution, remote control etc.

Nanoelectronics

The electronics and semi-conductor industries have been one of the biggest components of the global high-tech economy and have continuously blazed the path with breakthrough innovations. Nanotechnology, with new materials and processes, has the potential to fundamentally alter these industries by enabling new devices, architectures and applications. There has been a lot of speculation and discussion on the role nanotechnology will play in the future of electronics

The demands for more sophisticated electronics and

the production of electrical components smaller than the limits offered by traditional lithographic techniques have led to rapid growth in the development of new processing techniques on the nanoscale. It is vital that properties measured on such small scales are accurately measured and traceable to accepted macroscopic standards. In addition in nanostructures the electrical properties can be markedly different from their macroscopic equivalents thereby revealing many novel effects. Emerging techniques for the fabrication and study of structures on the nanoscale are being employed to construct devices and explore their potential as modern standards.

Electrical nanostructures have many applications as metrological quantum standards or as tools for nanoscale metrology. Well established examples are the quantum Hall effect for resistance and the Josephson effect for voltage. Nanostructures being explored are the fabrication of atomic wires, the study of spin-polarised electronics and magnetic nanostructures. Future applications could range from quantum computing and so-called "safe" quantum communication, to devices for single-particle sensor technologies, nanoscale frequency standards and the study of adatom-surface interactions.

The quantum effect on which most of these devices are based are very weak and the measurement technology is of paramount importance. Areas being studied include the fabrication of atomic wires; single electron tunnelling (SET) devices and atto-farad structures; and the study of spin-polarised electronics and magnetic nanostructures - all of which are likely to play an important part in future electronic devices. A study of the thermal motion of an isolated surface-trapped atom will also be carried out and its potential as a nanoscale noise thermometer investigated.

Work in the area of quantum-based devices for nanoscale metrology will be directed to fabricating an ultra-small SQUID for applications in single-particle detection. The fabrication of such a device will be a significant achievement, and should prove important in areas such as future nanoscale frequency standards, emerging quantum computer and single-particle sensor technologies and in the study of adatom-surface interactions.

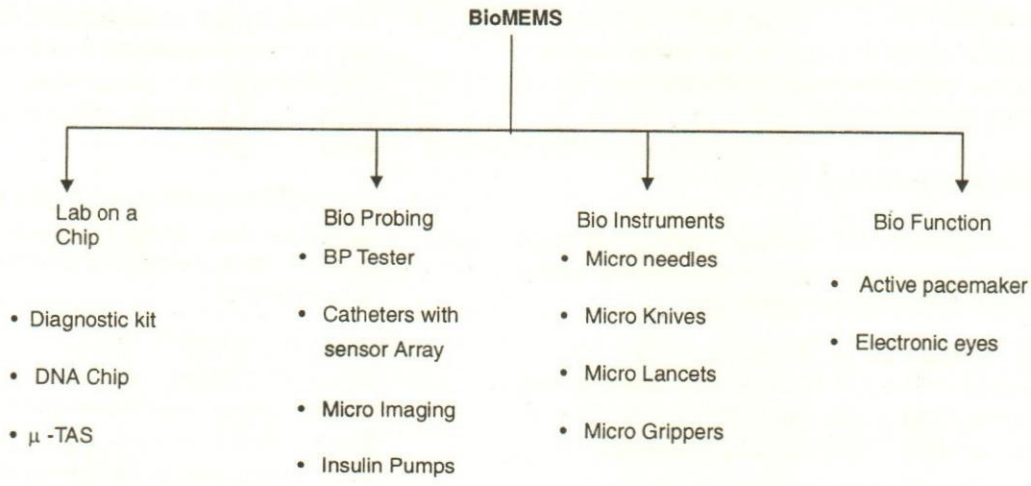
Areas being studied include the fabrication of atomic wires; single electron tunnelling (SET) devices and atto-farad structures; and the study of spin-polarised electronics and magnetic nanostructures - all of which are likely to play an important part in future electronic devices. Thermal motion of an isolated surface-trapped atom will also be carried out and its potential as a nanoscale noise thermometer investigated.

Micro-electromechanical Systems (MEMS)

As the name suggests micro-electromechanical systems (MEMS) include all those devices which have dimensions in microns and have both electronic and mechanical components together. It is an enabling technology that combines the processing capability of electronics with the work capacity of mechanics to achieve functions attainable no other way. Batch fabricated miniature are devices that convert physical parameters to or from electrical signals and which depend on mechanical structures to parameters for their operation.

The major advantage of MEMS are low cost, power saving, portable and smart appliances, availability and accessibility, environment friendly and safe systems, alternatives to painful medical procedures, security and identification, smart positioning, rapid progress in e-medicines, disable assistance systems, shock proof devices, mass production, new business models, utilization of obsolete fabs, seamless integration with microelectronics, material cost saving, low weight etc. MEMS is an established enabling technology and there are a large number MEMS components available from international vendors. Some of these components are pressure, temperature, chemical, and magnetic sensors, Accelerometers, rate gyros, fluidic sensors, actuators, microvalves, thermal switches, variable emissivity surfaces, Microthrusters, Synthetic jet actuators, Micropower generators, Microrelays switches, Micro RF switches, Variable capacitors, Inductors, Micro-optoelectro-mechanical devices, integrated devices, springs, bearings, gears, connectors. These MEMS components find applications in almost all sectors of science, engineering and industry e.g. sensors, medical and clinical, RF and optical communications, automotive health and status monitoring, transportation system monitoring, aerospace vehicle navigation and control, intelligent consumer goods, manufacturing process monitoring and control, spacecraft systems, miniature spacecraft and air vehicle design, personal computer peripherals, computer–aided manufacturing, robots, remote sensing.

BioMEMS takes advantage of interfacing MEMS components with functional biomolecules to enhance their capability and performance for host of engineering and healthcare applications. Some of the applications of bioMEMS include DNA analysis tools called micro-arrays and the camera pill, a swallowable capsule with a tiny camera that provides diagnostic images of the small intestine. The market opportunities in bioMEMS are specifically designed for biological and healthcare use. The latest applications such as therapeutic microchips and DNA repair are moving in that direction. The ultimate goal



BioMEMS for healthcare/medical applications

of this technology is to create fantastic therapeutic chips that are able to go inside the body, feel, diagnose, sense and repair. Such a device is no more inside the realm of science fiction.

There is plenty of interest in bioMEMS because of its role in medical applications particularly for diagnosis with minimal amount of sample and instrumentation for minimal invasive surgery.

The manufacturing of bioMEMS devices differ from IC manufacture because the market requires a diversity of materials, physical structures, input/output methods, products, and initially lower volumes per product. This creates an obvious need for modular, non-silicon approaches to building inexpensive disposable chemical and biological sensors and systems. The non-silicon materials include glass, PMMA, polymers, metals and ceramics. The developments of bioMEMS also face technical challenges due to the integration of microelectronics with microfluidics; thus, there is role of careful packaging. Self-assembly of biomolecules on chip surface poses a challenge, the reason being that without it, commercial fabrication of bioMEMS is impossible. Certain techniques have been demonstrated in the laboratories; but, these do not scale up into manufacturing technologies. So self-assembly is an important biological principle in commercial manufacturing of bioMEMS.

Recent developments in fluidics, microelectronics and detection techniques have matured the use of bioMEMS for various biomedical applications. For instance, the microfluidic chips now compete in routine applications with many conventional test devices. It has now become obvious that miniaturisation alone is not the key factor for success. Nowadays, microfluidics in integrated devices incorporate multiple fluidic assay functions like blood separation, metering, resuspension, fluid transport and detection. Thus, design, function, fabrication and application have an impact on the technical and commercial success of bioMEMS.

The technical problems that occur in the development and manufacturing of bioMEMS include the assembly of metals and polymer and the surface chemistry. The air bubbles in channels and the mixing of fluids in laminar flows as well as the handling of samples i.e. blood and urine. Similarly the requirement for low cost disposables and the scaling up production from prototypes and first series to volume production are problems related to commercial production.

Self-assembly is one of the great challenges in nanotechnology, for the simple reason that without it, commercial nanotechnology is impossible. Certain groups are working on the use biomolecules like proteins and DNA for the self assembly of materials. For example DNA has been shown to precisely form cubes, knots and circles at the nanometer level. It has been shown that DNA-based structures can form cages and hold molecules between them. So it can be used for precise positioning of molecules at the level of few nanometers. Similarly marine organisms e.g. radiolaria can assemble into wonderfully complex skeletons.

Bacteria use the whip-like motion of their flagella (a long filament) to move around. While each flagellum normally turns counter-clockwise about 80 per cent of the time, it is possible to introduce a mutation that will lock the motors in one direction of rotation, either clockwise

or counterclockwise. Thus, a single bacterium can be used as a flagellar motor or pump. A number of bacteria, all rotating in the same direction, could be used as an inexpensive tiny conveyor belt.

Nanotechnology in industry

Nanotechnology products are penetrating into large number of industries for commercial exploitation. Some of the successful industrial examples are:

- Stain-repellent Eddie Bauer Nano-Care khakis, with surface fibres of 10 to 100 nanometers, use a process that coats each fibre of fabric with "nano-whiskers," developed by Nano-Tex
- Burlington Industries subsidiary, Dockers also makes khakis, a dress shirt and even a tie treated with what they call "Stain Defender." This will have impact on dry cleaners, detergent and stain-removal makers, carpet and furniture makers, window covering makers etc
- Polymer dispersions are found in exterior paints, coatings and adhesives, or are used in the finishing of paper, textiles and leather
- Many vitamins and their precursors, such as carotinoids, are insoluble in water. However, when skillfully produced and formulated as nanoparticles, these substances can easily be mixed with cold water, and their bio-availability in the human body also increases. Many lemonades and fruit juices contain these specially formulated additives, which often also provide an attractive colour.
- In the cosmetics sector, BASF has for several years been among the leading suppliers of UV absorbers based on nanoparticulate zinc oxide. Incorporated in sun creams, the small particles filter the high-energy radiation out of sunlight. Because of their tiny size, they remain invisible to the naked eye and so the cream is transparent on the skin. BASF's annual sales of aqueous polymer dispersion products amount to around $1.65 billion
- Nanodyne makes a tungsten-carbide-cobalt composite powder (grain size less than 15nm) that is used to make a sintered alloy as hard as diamond, which is in turn used to make cutting tools, drill bits, armor plate, and jet engine parts
- Kodak is producing OLED colour screens (made of nano structured polymer films) for use in car stereos and cell phones
- Using aluminum nanoparticles, Argonide has created rocket propellants that burn at double the rate and copper nanoparticles that are incorporated into automotive lubricant to reduce engine wear
- AngstroMedica has produced a nanoparticulate-based synthetic bone. Human bone is made of a calcium and phosphate composite called Hydroxyapatite.
- Used in packaging, like beer bottles, as a barrier, allowing for thinner material, with a subsequently lighter weight and greater shelf-life. This has an impact on the $480 billion packaging and $300 billion plastic industries. Reduced weight means transportation costs decline. Changing from glass and aluminum - for beer and soda bottles - to plastic reduces production costs.
- Nanoclays help to hold the pressure and carbonation inside the bottle, increasing shelf life. It is estimated that beer in these containers will gain an extra 60 days (from 120 to 180) of shelf life, reducing spoilage, and decreasing overall costs to the end user.
- Nanocor is one company producing nanoclays and nanocomposites, for a variety of uses, including flame retardants, barrier film (as in juice containers), and bottle barrier
- A plastic nanocomposite is being used for "step assists" in the GM Safari and Astro vans. It is scratch-resistant, light-weight, and rust-proof, and generates improvements in strength and reduction in weight, which lead to fuel savings and increased longevity
- Toyota started using nanocomposites in a bumper that makes it 60% lighter and twice as resistant to denting and scratching, thus lowering weight, increasing mileage and creating longer-lasting autos
- Nanoledge makes carbon nanotubes for commercial use, of which one mundane (marketing tactic) use is in a tennis racket, made by Babolat. The yoke of the racket bends less during ball impact, improving the player's performance
- China's largest coal company (Shenhua Group) has licensed technology from Hydrocarbon Technologies that will enable it to liquify coal and turn it into gas. The process uses a gel-based nanoscale catalyst, which improves the efficiency and reduces the cost

- Argonide Nanomaterials, an Orlando-based manufacturer of nanoparticles and nanofiltration products, makes a filter that is capable of filtering the smallest of particles. This disposable filter retains 99.9999+% of viruses at water flow rates several hundred times greater than virus-rated ultra porous membranes.

Challenges

Priority areas are:-

(1) research to enable the nanoscale as the most efficient manufacturing domain

(2) innovative nanotechnology solutions to biological-chemical-radiological-explosive de-tection and protection

(3) development of instrumentation and standards

(4) the education and training of the new generation or workers for the future industries

(5) partnerships to enhance industrial participation in the nanotechnology revolution.

The convergence of nanotechnology with information technology, modern biology and social sciences will reinvigorate discoveries and innovation in almost all areas of the economy. Nanotechnology has the potential to make substantial improvements in the general quality of life and is, therefore, drawing the attention of entrepreneurs and investors around the globe. Recent product launches, such as transparent sun blocks, stain-free fabrics, golf balls designed to fly straight, and nick-proof trims on hummers, clearly demonstrate the enormous potential of the technology to provide superior medical treatments, better production processes, faster computers, and smaller memory devices.

With many more nanotech-based products presently in their developmental stage and expected to be launched within the next few years, the nanotechnology industry is currently in the late introduction or early growth phase and, hence, faces numerous challenges. An added challenge for nanotechnology companies is the lack of sufficient consumer knowledge concerning the benefits offered by nanotechnology, as well as the complex nature of such products.

"Initially, nanotechnology products are expected to be more expensive than traditional products," notes the analyst of this research. "Convincing the customer that the added value is worth the additional cost will be key determinant of the growth of this technology."

The Role of Industry

Nanotechnology and MEMS research and development is high in cost, infrastructure and trained manpower incentive, and very few industries in a country like India can afford it. But there is huge potential and good opportunity for small entrepreneurs and start-up companies to take advantage of the ever-growing market of these advance areas of technology.

Development of MEMS components and nano-devices including nanoparticles is one aspect of commercial products in this area, but the major challenge is to give value addition to these products to make marketable finished products/systems. The Government of India has taken major initiative in the area of MEMS and nanotechnology for the development of selective products. These initiatives are not sufficient unless industry participates to take research into the market.

In fact keeping in view the rate at which these technologies are growing in the international market, industry can play a major role in developing finished products for wide-ranging applications in engineering, healthcare and science by utilizing basic MEMS components and nanomaterials commercially available from international vendors through the value addition route. In this direction some of the key applications can be MEMS-based healthcare devices, sensors for agriculture, temperature/pressure sensors, surface modifications of cutting tools, surgical tools artificial jewelry and decoration articles. System design on commercially available MEMS components is a huge lucrative market and imagination is the limit for their application. Industry should also take active participation with R&D organizations for taking maximum advantage of these technologies.

- Participation in the Nanotechnology Programme – cash and kind
- Catalysis, paints, BioMEMS, composites
- Invest today for future huge profit
- Explore biodiversity for nanomaterials & devices – skull to heart
- Sensors – biosensors
- Calculated risk

Bionanotechnology & BioMEMS reseach at CSIO

CSIO is actively involved in the development of biomoleculear and nanodevices for engineering and medical applications. During this period CSIO has gen-

erated state-of-art expertise and facilities for focused research for development of specific devices for biomolecular electronics, disease diagnosis and targeted drug delivery based on molecular devices working in living systems. For this CSIO has created a cross multi-disciplinary team consisting of scientists and PhD students from physics, chemistry, molecular biology, biochemistry, zoology, metallurgy, semiconductors, biophysics, electronics, electricals, mechanical, software, material science, medical engineering, biotechnology, etc.

The group is taking a multi-disciplinary integrated approach to various projects to understand physical and biological processes at molecular level for designing devices out of DNA as a nanowire, Bio-MEMS for disease diagnosis, biomolecular motors for nano electronic switching and targeted drug delivery. Carbon nanotubes are studied for sensors, actuators and targeted drug delivery.

DNA nanowire-based devices

DNA is the best molecular electronic device ever produced on the earth because DNA can store, process and provide information for growth and maintenance of a living system. All living species are as the result of a single cell produced during reproduction. In most of the cases this single cell does not have most of the materials required for fabricating a living system but contains all the information and processing capability to fabricate living spaces by taking materials from the environment, for example, fabrication of a baby from Zygote which contains rearranged DNA sequences of parents. DNA is ready to use nanowire of 2 nm and can be synthesized in any sequence of four bases i.e. ATGC. DNA of every living organism (micro/macro) consist of a large number of DNA segments where each segment represents a processor to execute a particular biological process for growth and maintaining life. Other important characteristics of DNA which makes it material of choice for future molecular devices are: more information in 1ml of DNA than trillion CDs, four bases (A,T,G,C) instead of 0 and 1, extremely energy efficient 10^{-19} operations per job, synthesis of any imaginable sequence is possible and semiconductor are approaching limit.

CSIO has already developed DNA-based encryption where all the 256 ASCII characters have been defined in terms of four bases (A,T,G,C) and using a dedicated software developed at CSIO any text or picture (digital information) can be encrypt into DNA sequence (International Patent filed). We have also defined number systems and arithmetical operations in terms of DNA sequences which can handle up to rational numbers. Work on complex numbers is in progress. This is an important achievement towards molecular ultra-high density memory devices. For example, the national flag can be coded in terms of a DNA sequence of 7924 bases i.e. in our single genome (containing 6.4 billion bases) tricolour can be copied almost a million times. Space occupied by a genome is only few nm^3. At CSIO we are studying electrical behaviour of various segment of DNA to understand their information processing capability using Femto range (10^{-15}) IV-CV measurements.

This study is the first of its kind and will have a tremendous impact in realizing biomolecular electronics and sensors, which nature has perfected in millions of years. For these studies we are binding different DNA sequences on micro/nano electrodes. We are also exploring the various ways in which DNA sequences can be hybridized with semiconductors to have dedicated processors with ultra-high speed and density.

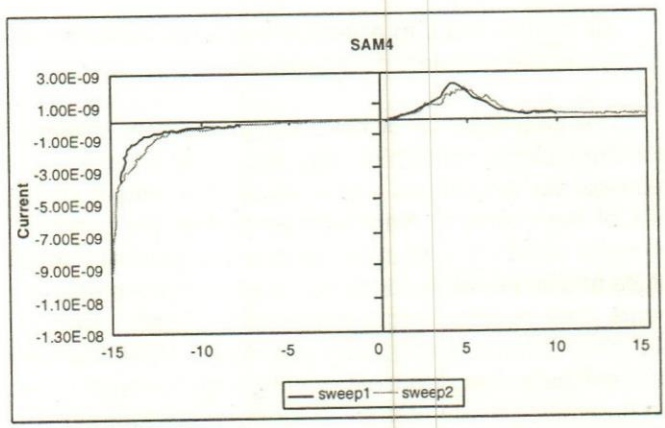


Fig. 1. Current–voltage Measurement on DNA Molecule

The data on charge transfer to DNA will be of immense importance for fabrication of DNA-based molecular electronic devices with dimensions a few thousand times less than semi-conductors with processing power manifolds. Understanding of charge transfer in DNA will revolutionize our basic knowledge in elucidation of life processes as charge transfer between molecules and atoms is the key to all chemical and biochemical processes. In turn this will help in understanding DNA damage chemistry during diseases such as cancer, HIV etc.

Bio-MEMS based Microdiagnostic Kits

The bio-MEMS based sensors are creating a lot of interest because of their numerous advantages over the most advanced techniques currently employed. The high specificity of the sensors is provided by the biomolecular

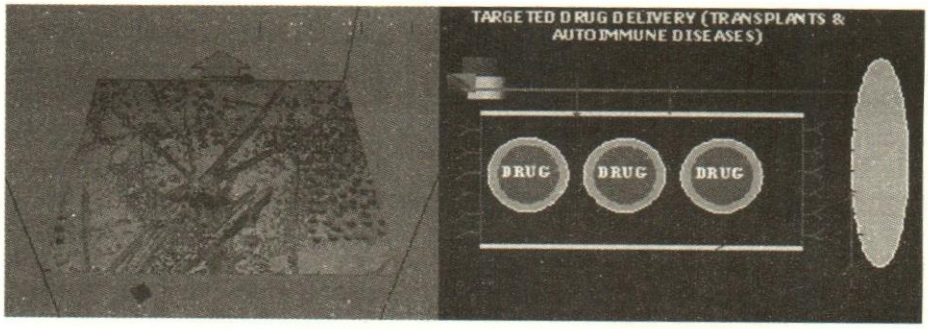


Fig. 2. Carbon Nanotube-based AFM image and Targeted Drug Deli very Concept

recognition characteristics of antigen-antibody, probe DNA-target DNA, protein-receptor and enzyme-substrate. The change in mass on the microcantilever surface due to the binding of the analyte molecules is directly proportional to the deflection of the microcantilever.

CSIO achieved a major success towards development of disposable micro-diagnostic kits for diseases by developing innovative techniques for binding antibodies on cantilever with surface coverage greater than 65%. With this achievement it will be possible to have sensitive devices based on 0.5 micron thick cantilever design. This concept has been validated by theoretical simulation.

Cost of this disposable micro-diagnostic kit is targeted at about Rs 20-25 per diagnosis and there is a time period of only a few minutes in comparison to presently used culture techniques which take a few weeks time and cost about Rs 500 to Rs 1000. The amount of blood sample and reagents is also reducing this techniques by a factor of 100-1000 i.e. only by a few microlitres. This concept can be extended to a large number of diseases and monitoring toxins in the environment including drinking water and food (processed and fresh). There exists a huge global market (millions of devices per year).

Nanotubes based Sensors and Targeted Drug Delivery

Carbon Nanotubes (CNT) are tiny molecular tubes made up of Hexagonal carbon rings joined together. Dimensions of these tubes range from 1 nm to 10s of nm depending upon their structure i.e. single wall or multiwall. These tubes have wonderful electrical behaviour which can be tailored simply by changing orientation or angle of bending. Carbon nanotubes are one of the most dominant materials for fabrication of molecular electronic devices with ultra high packing density and performance. CNTs filled with medicines are well suited for targeted drug delivery. Nanotubes have been synthesized from a large number of other materials such as vanadium oxide, boron nitride, $B_xC_yN_x$, WS_2, Rossette, $NiCl_2$, NbS_2, Ti_2O, MoS_2 etc Organic, inorganic and bio-nanotubes will be studied for their applications in engineering and medical applications.

CSIO has functionalized carbon nanotubes with functional groups such as COOH, NH_2 and OH for binding biomolecules such as DNA, antibody-antigen, bio-receptors and proteins for developing nanoimpantable sensors and actuators. On this basis we have designed a targeted drug delivery system shown below in which carbon nanotubes are filled with drug and encapsulated using disease receptors based bio-membranes.

Interfacing biomolecules with carbon nanotube will be of immense importance in the development of highly sensitive and selective miniaturized biocompatible sensors and actuators with dimensions in micro and nano range. These will revolutionise in-vitro early diagnosis and targeted drug delivery.

BioMolecular Motors

In living systems various kinds of movements of vital organs and muscles take place through different systems of molecular motors, such as, myosin-actin, microtubules-kinesin, microtubules-dynein, micro-tubules-bacterial flagella motor etc. It is possible to extract motors from their native environment, prepare assemblies of them on a plane surface. For these motors to be useful in nanofabrication it is essential that external control can be applied to the following properties: (a) translocation speed; (b) translocation direction; (c) activation and ar-

rest. These characteristics can be controlled by altering the chemical and/or the physical environment of the motors.

At CSIO we are making in-vitro studies on myosin actin systems which are responsible for our muscular movements to control the movement of actin against myosin in predictable and reproducible manner using myosin coated channels on silicon wafer. Study of this system under various electrode potentials, buffer, electrolyte, pH, etc. will help in the following:-

- Targeted drug delivery
- Designing molecular switches with ultra-high density, using low cost fabrication technique of molecular biology
- Understanding muscular movement and their diagnosis and cure

The development of commercially viable innovative bio-nano devices for high density memory, nano electronic devices, micro disposable and implantable diagnostic devices, targeted drug delivery etc. will revolutionise information processing, communication and health care.

Molecular motors are well established nano-scale molecular machines present in living systems that are responsible for various dynamic processes from transporting single molecules over small distances to cell movement and growth. Actin-myosin is a muscular motor protein system that converts chemical energy into linear motion for nanoscale transport. In-vitro motility assay is an experimental technique which can be used to utilize molecular motors for nanodevice application.

Myosin was immobilized on different solid substrates like gold-coated glass slide, mica, silicon which involve both covalent binding using cross linkers like EDC, APTES, silanes and non-covalent binding employing Protein A, surface adsorption. Atomic force microscope was used to investigate topological characteristics of different surfaces.

The velocity of actin filaments sliding over myosin heads is calculated using a tracking programme developed in MATLAB. Velocity of actin filament on myosin tracks immobilized on gold coated glass surface is found to be 1.81ìm/sec on mica surface is 2.99%m/sec and on glass slide cleaned with 0.1M KOH in ethanol is 3.65ìm/sec. In-vitro studies show that average velocity of the actin molecules was ranging from 1.0-1.5 %m/sec at pH 8.0. Microchannels are fabricated on gold coated glass surface by ablating the surface using laser micro dissection system to control the position of the actin filaments.

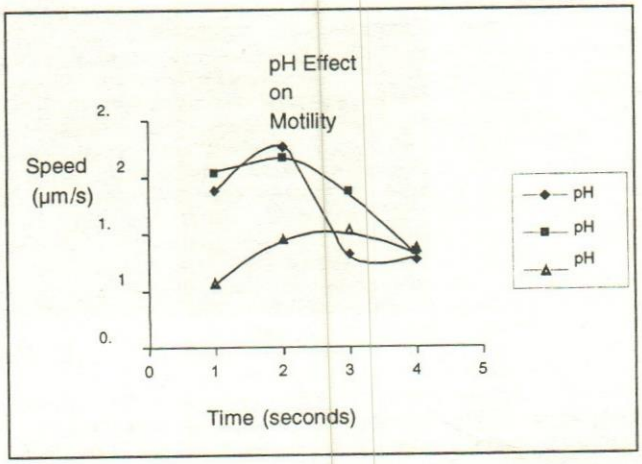


Fig. 3. Effect of pH on motility of the actin

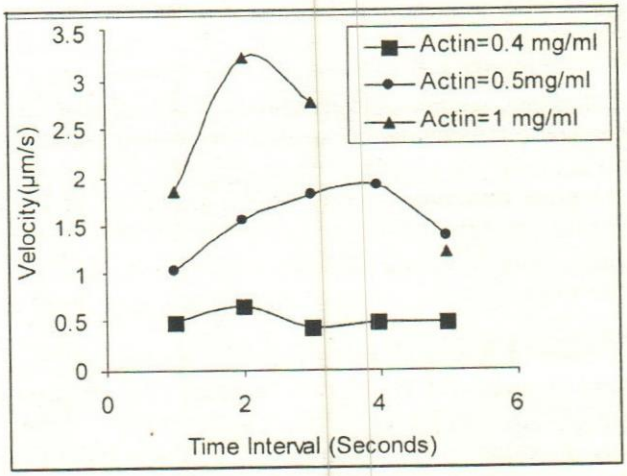


Fig. 4. Velocity at different actin concentration

Nanorobotic application of the system has been demonstrated by transportation of caorboxylated polystyrene microbeads attached to actin filament.

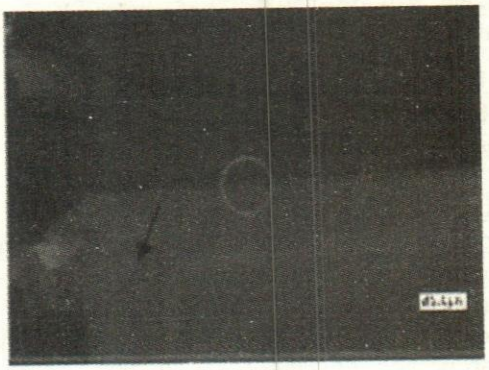


Fig. 5. Controlled movement of actin filament in Microchannel

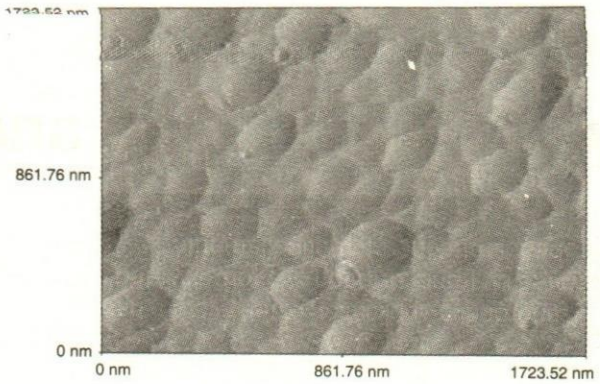


Fig. 6. AFM image of myosin on Glass Surface

Experiments are in progress to control directionality as well as the movement of actin filaments, by varying environmental conditions in terms of electrical and magnetic field, pH, temperature etc.

Stem Cells & Tissue Engineering

Stem cells are immature clonogenic self-renewing progenitor cells that have the capability to give rise to populations of mature functioning cells. Stem cells can be derived from bone marrow or from specific organs to carry certain genes which may have a desired effect e.g. therapeutic genes to site of disease may help in remodeling of the diseased organ, allowing them to have the corrective genes. The stem cells are divided into two groups. The first one are totipotent embryonic stem cells derived from inner cell mass of blastocyst and capable of generating all differentiated cell types in the body. The second group includes organ or tissue specific pluripotent stem cells, which generate the stem cell comprising of a particular tissue in embryos and adults.

The advent of the genome facilitated by advances in micro and nanotechnology has revolutionized the understanding of living systems. DNA micro arrays, catalytic RNA arrays and protein arrays are all consequences of innovation in engineering at micro and nano scales. We wish to use the natural ability of stem cells (charge, dielectric permittivity) for rapid manipulation of cells in a microarray format. The protocol shall use two methods of cell manipulation:-

(1) Electrophoretic arraying of cells in a DC field due to their intrinsic negative surface charge and

(2) Remote optical manipulation of individual cells by optical tweezers and laser scalpel.

In addition to this we also wish to interface these cells to silicon materials using cell surface receptors to make implantable disease corrective devices. These offer the possibility of a renewable source of replacement cells and tissues to treat diseases like Parkinson disease. We propose to develop tailored materials by hybridizing different cell lines to produce composite material with different tissues and non-biological materials. To achieve this nanoparticles of metals, nanotubes etc. will be interfaced during culture of stem cells for growing composites of desired properties. These composites will be grown under different media and membranes including solid surfaces. The possibility of hybridizing a desired cell line with tumor cells for the fabrication of custom biological materials in bulk shall also be explored in the present study.

This research will open an entirely new domain of material processing and synthesis as nature is fabricating innumerable materials through this process with entirely different properties such as bone, heart tissue, optical system of eyes, skull, bark of trees leaves, hairs etc. Thus with proposed methodology it is possible to synthesize all kinds of materials in terms of mechanical, electrical, thermal properties. These materials can have unlimited application in every sector of the economy including defence, electronics, textile, packaging etc.

Acknowledgement

The work presented in this article has been carried out by a multi-disciplinary team consisting of scientists and students with basic background in engineering, life sciences and basic sciences. Author is thankful to all of them for their contribution and suggestions and to Director, CSIO for providing institutional support. Author is also thankful to DST, DBT, DIT for financial support.

□

The single biggest problem in communication is the illusion that it has taken place.

– George Bernard Shaw

Nanotechnology: Catalysts, Adsorbents and Societal Concerns

Tirupati Reddy Keshav & Suddhasatwa Basu

'Nanotechnology' refers to the ability to measure, manipulate and organize matter at the atomic level. Some of the most important applications of nanostructured materials are catalysts and adsorbents for chemical processing. In this paper, the synthesis of nanoscale materials i.e., nano-structured catalysts, adsorbents and their applications in chemical processing and their impact on society has been discussed. Significant efforts have to be made to increase public awareness of this new field in order to avoid unexpected and/or unwarranted backlash.

Tirupati Reddy Keshav is with the HDST research Group, Dept. of Chemical Engineering, G.V.P College of Engineering, Visakhapatnam, Andhra Pradesh; and Suddhasatwa Basu is faculty at the Department of Chemical Engineering, Indian Institute of Technology Delhi, New Delhi

'Nanotechnology' refers to the ability to measure, manipulate and organize matter at the atomic level. There are one billion nanometers (nm) in 1 m (the width of a human hair is approximately 80,000 nm wide). Manipulation at atomic level makes it possible to produce mechanisms with capabilities far superior to many current devices. It has been found that the mechanical, electrical, optical, thermal, and magnetic properties of a nanoparticle are different from that of its bulk material.

The discovery of new synthesis processes and the demonstration of the highly reactive properties of nanostructured materials have increased rapidly over recent years. The new synthesis processes have made available nanostructured materials in a wide variety of compositions of metal oxides and metals supported on metal oxides, which have led to recognition of their exceptional chemical, physical, and electronic properties (Lewis, 1993). Some of the most important applications of nanostructured materials are catalysts and adsorbents for chemical processing. Recent studies have concentrated on the application of chemical engineering reactor design and fluid-flow technology to the synthesis of nanostructured materials as advanced catalysts. For all advanced catalyst work where one is attempting to improve selectivity and reactivity via metal ion modifications of a host metal oxide or alloy, phase purity is the most essential property of the synthesized catalyst. The contamination of the ion-modified catalyst by even small amounts of separate phase materials can lead to over reactivity of undesired products or deactivation of the catalyst. The increasing industrial applications for adsorption have stimulated a growing interest in research. The economics of all adsorption processes are also limited by the sorbent and thus improvement in the sorbent will lead to improved economics. Hence, major advances in gas adsorption technology will come from the development of new sorbents. For this reason, special attention has been given to new nano-scale sorbent

development over the last decade. In this paper, the synthesis of nano-scale materials, i.e., nano catalysts, adsorbents and their applications in chemical processing and impact on the environment has been discussed.

Nano-scale materials

The discovery of the synthesis of nano-scale materials that gives you systematically varying grains in the range 1-20 nm, is exceptionally important to the discovery of highly active and selective nano-scale materials. The older methods have recently produced nanostructured grains and particles in controlled morphologies due to a concentration on the chemistry required for the formation of fine grain materials. Many of the newer processes have required the development of special hardware and equipment to give particle isolation. Some of the important methods are sol–gel and precipitation technologies, combustion flame–chemical vapour condensation process, gas phase condensation synthesis, reverse micelle synthesis polymer-mediated synthesis, protein microtube–mediated synthesis and sonochemical synthesis.

CF-CVC Process

The starting materials for the CF-CVC (Combustion Flame–Chemical Vapour Condensation) process are metal complexes that can be vapourized and fed into a flat flame, which immediately converts the compounds to nanostructured metal oxides. Fig.1 shows the equipment that is used for producing nanostructured materials through the continuous CF-CVC process, which is developed by Kear and co-workers (Skandan et al., 1996; Tompa et al., 1999). The particle dilution is controlled to prevent agglomeration in a hot state in the flowing gas stream. The solid particles are then collected on a cold surface and scraped off continuously into a powder bin. A variety of simple and complex metal oxides have been produced in this way, including silica, alumina, titania, barium titanate, zinc and copper oxides. This process is similar to the Cabot process (Jordan et al., 1990), but it uses advanced flame design and control to afford better dispersion of the nanostructured grains.

Protein microtube–mediated synthesis

This method uses the protein α, β-tubulin after a self-assembly into 25-nm-diameter microtubes, which are several micrometers long. The surface of the protein contains thiol and ammonium end groups, which are reacted in aqueous solution with Na_2PdCl_4, followed by citrate reduction. It is a new process developed by Behrens et al. (1999) for the synthesis of nanostructured metals and alloys in varying grain sizes supported on hollow, highly oriented protein templates. Figure 2 shows the schematic of the synthesis of nanostructured metals and alloys in varying grain sizes supported on hollow, highly oriented protein templates.

The grain size of the palladium synthesized in this way was reported to be 2 nm. A similar synthesis resulted in 2-nm Au particles. Upon treatment of the microtubes with $HAuCl_4$, followed by $NaBH_4$ reduction and further reaction with Na_2PdCl_4 and followed by citrate reduction led to nanostructured Au/Pd alloys. By increasing the Pd/Au ratio from 2.3 to 10, the grain size of the alloy could be systematically reduced from 62 to 4 nm.

Sonochemical Synthesis

This method of synthesis most effectively uses metal carbonyls, which have a finite vapour pressure, as starting materials. The vapour pressure of the metal component inside a bubble formed by acoustic cavitation is key to the transfer of the very high heat generated during the bubble formation and collapse. This in-situ heat treatment converts the metal carbonyl vapors to nanostructured materials, which are especially active and selective as catalysts (Suslick et al., 1996). The most recent advances have been in the sonication of metal carbonyls in the presence of reactive substrates, such as the formation of nanostructured MoS_2 by sonicating $Mo(CO)_6$ in the presence of elemental sulfur (Mdleleni et al., 1998). Suslick's group has made many contributions to the application of sonochemistry to the synthesis of metallic and bimetallic catalysts (Suslick et al., 1999). Other studies have turned to the synthesis of carbides, sulfides, and nitrides using the same basic technique.

Sol–Gel and Precipitation Technologies

A continuous progress is made in the synthesis of nanostructured materials by sol-gel techniques in the synthesis of nanolaminates and solution-precipitation techniques (Schultz and Matijevic, 1998). The advantage of the sol-gel method of synthesis is that virtually any metal oxide system can be examined, and no special apparatus or equipment is required. The advantages of sol-gel processing are the formation of ceramics of high purity and good control over microstructure and particle morphology in the synthesis, typically at room temperature. Matijevic (1992) has shown that the precipitation of colloids may be accomplished in a wide variety of morphologies and grain sizes; however, in order to obtain

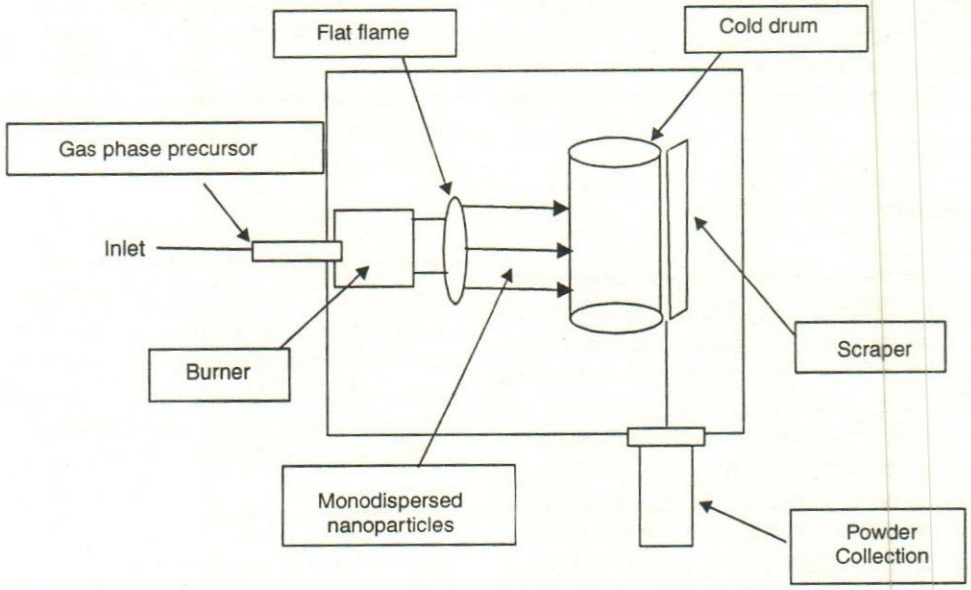


Fig. 1. The continuous CF-CVC process for producing nanostructured materials

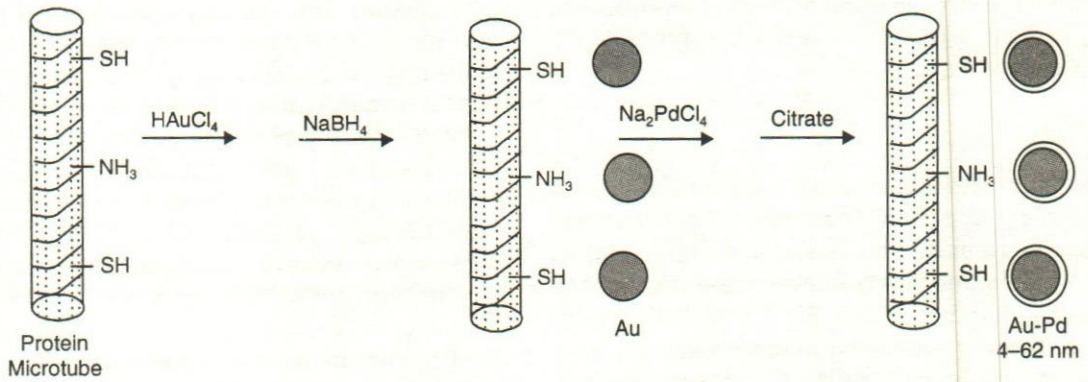


Fig. 2. Schematic of Protein Microtube-Mediated Synthesis

different morphologies and sizes, extensive chemical modifications must be made for each metal oxide system studied. The sol-gel technique works well for the synthesis of complex metal oxides with high phase purity because the polymerizing gel traps the various metal ion components spatially, permitting precipitation from solution where all the metal ions occupy near-neighbour positions in the gel matrix.

Gas Phase Condensation Synthesis

The newest development in the gas phase condensation process involved the use of dc and rf-magnetron sputtering to introduce metals into the gas phase instead of induction heating used by Gleiter (1989) and Siegel (1991). The equipment used in this type of process is similar to that shown in Fig. 1 except that the starting material is usually a pure metal that is introduced into the vapour phase by various heating methods. The metal vapour is then transported by an assisted gas stream onto a cold surface where it is collected. The resultant powder may be used as is or subjected to a controlled oxidation to produce the nanostructured metal oxides.

Reverse Micelle Synthesis

The reverse Micelle approach continues to grow in importance in the synthesis of nanostructured materials. The basis for the technique is the use of a surfactant to stabilize varying aqueous droplet sizes in a hydrocarbon medium. Metal salt precursors are contained in the aqueous portion and are transformed by a reactant from the hydrocarbon phase. Both the structure of the surfactant and the steric size are able to produce metals having a wide range of grain sizes. Although notable grain-size control has been observed, the technique has a major

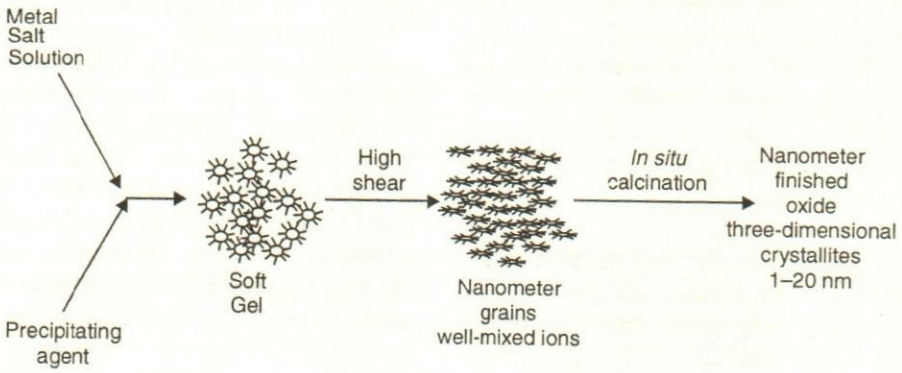


Fig. 3. Schematic of a typical hydrodynamic cavitation synthesis of metal oxides

disadvantage in that the commercial application may be limited due to the large amount of organic surfactant surrounding the crystals, and when this is removed by washing, the nanostructured metal grains normally grow. Poly(oxyethylene)nonylphenyl ether has been used in a combined synthesis of nanometer grains of silver on fine-grain silica (Li et al., 1999).

Polymer-mediated synthesis

A potentially important, new nanostructured metal-particle synthesis technique based on mediation by polymeric materials might overcome the problems associated with the large amounts of surfactants required in micelle processes. The general synthetic technique is based on the reduction of a platinum salt (Zhao and Crooks, 1999) or palladium salt (Zhao and Crooks, 1999b) with aqueous $NaBH_4$ in the presence of a hydroxyl-terminated dendrimer. The dendrimers are monodispersed, hyperbranched polymers having a very high concentration of surface functional groups. Twelve to 60 Pt^{2+} atoms can be loaded into a poly (amidoamine) dendrimer (PAMAM) and reduced to the metallic nanostructured grains. The interesting aspect about this method of synthesis is that the reduced metal could be extracted in to hydrocarbon solution, leaving the polymer behind. Nanostructured metals prepared by this technique have been found effective as catalysts for electrolytic O_2 reduction and allyl alcohol hydrogenation.

Nanostructured Catalysts

The classical approach to the synthesis of nanostructured catalysts and materials of different morphologies and grain sizes has been one that heavily relies on detailed experimentation, altering the chemistry of synthesis to achieve the desired material. Many catalytic reactions were reported to show greatly accelerated reaction rates for samples where the catalyst primary grain sizes were in the range 1–10 nm. The importance of a catalyst preparative technique that enables one to systematically change the grain size to any value in the range 1–20 nm is the one some show a maximum in reactivity. The optimum grain size differs depending on the catalytic reaction. Many processes result in the formation of multi-metallic catalysts in high phase purities, which is important for catalysis. Hydrodynamic cavitation processing affords the capability to calcine precipitated products during the synthesis step and to systematically introduce crystallographic strain. In some cases, the hydrodynamic cavitation process afforded variable catalyst grain sizes in the range 1–10 nm by a simple mechanical adjustment in the process parameters, but metal oxide synthesis did not generally result in a large variation in grain sizes.

The objective of the research on hydrodynamic cavitation was to use the high Reynolds numbers and controllable throat cavitation numbers to regulate synthesis of both metal oxides and supported metals and metal oxides. Figure 3 shows the schematic of a typical hydrodynamic cavitation synthesis of metal oxides starting with a metal salt solution, which is precipitated and processed in a cavitating stream of bubbles. The equipment currently used for hydrodynamic synthesis was invented by Kozyuk (1996, 1998) and manufactured by Five Star Technologies, Cleveland, Ohio. The advantage of this equipment is that it incorporates the process variability necessary to regulate the bubble dynamics required for the synthesis objective.

Nanostructured Adsorbents

Energy storage, i.e., storage of methane and hydrogen, has attracted much interest, particularly for onboard-vehicle applications. Activated carbon has been the most promising candidate as the sorbent for both methane and hydrogen storage. Interests in hydrogen storage by ad-

sorption were intensified only recently. There are four possibilities for onboard hydrogen storage: compressed gas, liquefaction, metal hydrides and adsorption. The use of first three technologies is limited, where as there exist lot scope of improvement in adsorption technology. A recent claim on hydrogen adsorption in carbon nanotubes has stimulated intense interest.

The carbon nanotubes are derivatives of the C_{60} buckyball structure. They are formed by graphite (or graphene) sheets rolled up into tubes, generally in the range of 2 to 10 nm in diameter and 200 to 500 nm in length. The multi-wall nanotubes were described by Iijima (1991). Single-wall nanotubes were discovered in 1993. Since their discovery, these materials have attracted intense interests due to their potential in applications in a variety of nanotechnologies. Of particular interest in adsorption is hydrogen storage. Much excitement has arisen on recent reports of promising results on carbon nanotubes for hydrogen storage (Dillon et al., 1997). High hydrogen adsorption capacities were reported for various carbon nanotubes. Dillon et al.(1997) reported that single-wall nanotubes could potentially store up to 5 to 10% by weight of hydrogen at 273 K and 300 torr based on estimates from temperature-programmed desorption data. Chambers et al. (1998), using a volumetric system, reported up to 56% by weight of hydrogen storage by multi-wall nanotubes at 120 atm and 298 K. More recently, interesting results were reported for using alkali-doped carbon nanotubes for hydrogen storage (Chen et.al. 1999). It was reported that Li and K-doped carbon nanotubes adsorbed, respectively, 20 wt.% and 14 wt.% of hydrogen at 1 atm and mild temperatures (200 to 400 ^{0}C for Li-doped and near room temperature for K-doped nanotubes). A lower but still substantial amounts of hydrogen adsorption were also reported for alkali-doped graphite. Most recently, Liu et al. (1999) reported about 4% by weight of hydrogen adsorption in single-wall nanotubes, at 100 atm and room temperature. Needless to say, hydrogen storage with carbon nanotubes has tremendous potentials, yet it is in development stage. It is difficult, if not impossible, to reproduce data for several reasons. First, carbon nanotubes can be prepared in a number of ways, and it is difficult to reproduce the nanotubes prepared in another laboratory even if the same technique is followed. Second, leakage of hydrogen at high pressures is a notorious problem in the laboratory. In the measurement using a volumetric system, the signal for hydrogen adsorption is typically a few psi, which can be easily the amount of leakage.

Methane cannot be liquefied at ambient temperature (Tc = 190.6 K); hence, very high pressures (typically up to 25 MPa) are needed for the requirement of onboard storage. The pressure can be reduced by using sorbents. This subject has been investigated since the early 1980s. The target pressure for storage is 4 MPa. The interaction between methane and carbon is only by nonspecific dispersion forces. Among all activated carbons that have been investigated, the storage capacity is approximately proportional to the surface area. This proportionality is due to the wide pore-size distribution in the commercial activated carbons. Molecular simulations, however, showed that there is an optimal pore size (assuming slit shaped pores) for maximum storage, which is near 1.1 nm. Indeed, activated carbon fibers, which have relatively uniform pore sizes (near 1 nm), yielded higher methane-sorption capacities than activated carbons (Alcaniz-Monge et al., 1997). The best carbons have capacities near 200 NTP v/v at 4 MPa at ambient temperature, which is quite adequate for onboard-vehicle applications. The effects of typical impurities that are contained in the natural gas on the charge–discharge behaviour have been analyzed (Mota, 1999).There is possibility of potential applications of nano-structured adsorbents.

Societal concern

The ultimate goal of scientists and engineers involved in the development of nanotechnology is to see its endless applications realized to get rid of the world of disease, to create a renewable energy source, and to bring the human race safely into the next millennium. Funding for nanotechnology research and development includes nearly $3.7 billion for 2005–2008 in the US, £45 million per year until 2009 in the UK, $960 million in Japan for 2004, and one billion euros in Europe (Royal Society & Royal Academy of Engineering (2004)). What is being overlooked in the short term, however, is a largely unacknowledged factor that may bring a premature halt to this technology: the social and ethical implications of nanotechnology that are already causing concern within the discipline. Although a few nano-technology based organizations are looking into it, these issues are not getting the enough attention and funding. Unless the concerns related to ethics and social impacts are thoroughly addressed, the progress of nano-technology could be severely hampered. The greatest challenge facing nanotechnology is the confronting the public's lack of understanding. The concern does not originate in the science but in the public's skepticism of projected applications. Apart from those in scientific circles and science fiction fans, awareness of nanotechnology is nearly zero. Without an accurate understanding of the science, how can the average person give an informed opinion about future directions that science should follow and judge whether nanotechnology is in the best interest of mankind?

When analyzing societal issues, nanotechnology is currently at a disadvantage. Since the technology is still at an infancy, no potential future technology can be absolutely dismissed as impractical or theoretically impossible. The predicted applications are diverse and ambitious, and most are not yet approaching realization. At this point in the development, there has been speculation about what will happen and what will not happen. The developed countries dominate in technological advances, with both government and industry allocating money for research and development and subsequently profiting from the results. As demonstrated by information technology and telecommunications, advances in technology boost profit directly through product sales, and indirectly by attracting highly educated workers from developing countries. These technology developments create a growing economic divide between developed and developing countries. It is feared that the newest technology likely to add to this divide will be nanotechnology.

Developed countries and regions that dominate nanotechnology research, i.e. the United States, Western Europe, and Japan, are expected to be the first to benefit from nanotechnology applications. They have private-sector and government resources to invest in research and development work. The developing countries need to become well educated in new technologies if they want to benefit from cheaper, more effective medical devices, a more abundant energy supply, and less expensive materials and consumer products. Without relying on other countries for aid, the most effective way developing countries can benefit from nanotechnology is to invest in research within their own borders, as China and India are doing (Abdul Kalam APJ: 2004, Nemets. A (2004)). For example, President A.P.J. Abdul Kalam of India wrote an article published in the *Hindustan Times* in which he concedes that nanotechnology research in India has had 'modest beginnings' but that 'a lot more needs to be done.' He recognizes that nanotechnology 'will be the central focus for many technologies to converge and open a large number of applications' that will lead to a 'robust economy' (Abdul Kalam APJ: 2004). As a result India, along with China and South Korea, are the front-runners of nanotechnology activity among developing nations (Mantell K: 2004).

Privacy and security are threatened as communication technology advances and equipment becomes smaller in size. As electrical components become smaller and more sophisticated, it becomes easier to violate someone's privacy. Nanotechnology promises exponentially smaller electrical components and sensors for equipment like video cameras and computers. The same enhanced equipment that is capable of improving computational power can also be used to violate safety and security. It may become easier to extract personal information and violate personal privacy. How would the privacy of an individual be protected if near-invisible microphones, cameras, and tracking devices become widely available (Mnyusiwalla et.al: 2003)? However, the same miniaturizing technology that is capable of compromising our personal privacy is also capable of increasing our personal safety and security.

Military and law enforcement personnel can benefit from miniaturized video equipment and microphones and using them for surveillance in combat operations. A tiny undetectable microchip can be implanted in the skin of family pets and children to counter loss or deter kidnapping or to determine their whereabouts. This issue of privacy needs to be addressed by the nanotechnology community because it has the potential to affect everyone, both positively and negatively. From the above discussion it is obvious that the nature of construction-destruction paradox of nanotechnology on society has to be thoroughly evaluated before it can shape (re-shape?) the future of the world.

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He who does not understand your silence will probably not understand your words.

– Elbert Hubbard

Feature

Assessing Lean Operations: Methodology for the Service Industry

Nesa L'abbe Wu & Curtis Walker

The purpose of this paper is to propose a methodology for assessing lean operations in small to midsize service companies. The methodology requires the calculation of a lean office score based on four surveys, and a workplace organizational score. The methodology not only measures the level in which each operation is lean, but also points out the areas of deficit, so that improvements can be suggested and made. The implications of this methodology are reflected in a sample case, namely the main office of Time Share Company and its resorts.

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As lean consultants who visit companies around the country, it has been our experience that 'once the bug hits' to begin the journey towards lean achievement, many individuals want to simply dive in and start randomly implementing lean tools. While, on the one hand, their enthusiasm is heartening, on the other hand, they very often begin with items that are of less overall value or lower priority.

Many companies look at surveys as a perfunctory, unnecessary, or time-consuming effort that can just as easily be bypassed in order to get to the "real" work. The surveys described in this article help the fledgling lean company to assess the needs first and then apply the appropriate lean tool to the issue, rather than the other way round.

If a company has a genuine understanding of what lean is all about – continuous improvement – they will already know that this is a process that is ongoing. However, there is a logical or proper starting point. Only by assessing and understanding the culture within the company, and the issues that have an overriding impact, can we begin to determine how well and how long the lean conversion will take.

More often than not, companies are surprised by the results attained in surveys of employees and management. This does not mean that the results are always negative, simply surprising. Keep in mind that the perspective of any one group is different from another and that all points of view should be considered. An example of this lies in the company who is told by the "workers" that their procedures are lacking and/or confusing. Management then takes exception, saying that they spend plenty of time and money on creating them. While this may be true, the fact that the workers feel that these are inadequate should send a clear message to management.

As with any survey or assessment, you are looking for an overall or average score to tell you about the situation. However, it is also important to look for "patterns" in individual questions. For example, you might achieve an overall score of 4, but 22 out of 35 people gave Question 9 a score of 2. This is clearly a case where you are doing well overall, but that the issue in Question 9 needs to be addressed specifically and with greater priority.

In lean surveys it is best, where possible, to ask all employees to fill out the survey you are conducting. However, this is not always practical or possible. In that case, a random sampling is acceptable, providing it covers a wide enough base to get a true "read" on the situation. Provide space for handwritten comments and read these carefully. Feedback from surveys is critical. People want to feel like their opinion is valued and respected and that they can have a genuine impact on the improvement of their company.

Methodology

A successful or lean service company implies a company that is well organized; that is interested in continuous improvement; that listens to the voice of its customers; that tightly controls the cost of operations while eliminating waste; and that can be a benchmark for similar companies.

The proposed methodology that evaluates and measures how lean the operations are in any type of an office environment requires all of the following three steps:

1. Exhaustively interviewing all employees in the various offices of the company for the purpose of capturing the "lean office score."
2. Evaluating and capturing lean principles of work place and office operational procedures in a "work place organizational score" and/or a specific overall score for any major company function.
3. Evaluation of historical metrics of the company.

When implementing this methodology, one will also be able to identify key areas that need improvement so that the business can steer itself towards leaner operations.

The Interviews

A lean small office is characterized by cross training; non-specialized work content; non-excessive or known employee travel time; realization and understanding of waste; work load leveling and no work duplication. Well-designed interviews with all employees, together with personal observations will aid in analyzing these characteristics of an office.

GDC Total Business Solutions suggests the use of specific surveys for such interviews. These surveys have been published by MCS Media, Inc, 2003. They consist of three surveys for all employees and one survey for management:

1. A Predictable Output Survey (for all employees)
2. A Proof of Need Survey (for all employees)
3. A Lean Assessment Profile Survey (for all employees)
4. A Management Self Assessment Survey (for managers)

In order to calculate a "Lean Score", the above mentioned GDC surveys have been modified.

On a scale from 1 to 5 rate the following statements (1: disagree,, 5: 100% agree)	1	2	3	4	5
1. There are standard methods and processes that ensure the quality of work for each employee or work assignment.					
2. The methods and processes are continually improved upon.					
3. The methods and processes are made visible and are easily accessible.					
4. The methods and processes are documented.					
5. We have meetings that focus on the processes.					
6. Employees are able to make improvements/ changes, based on a systematic process.					
7. Most of my time is spent on value-added work.					

Fig. 1. Predictable Output Survey

Adapted from " Predictable Output Survey", originated by GDC Total Business Solutions and published by MCS Media, Inc 2003

Predictable Output Survey

A lean office exhibits standard methods and processes that ensure quality of work for each employee or work assignment. These methods and processes must be documented, made visible and easily accessible to all employees, and must be continuously improved. Employees must be encouraged to make changes to methods and procedures based on a systematic process. Meetings to that effect can be helpful. A large portion of

activities performed by employees must be value-added. The predictive output survey addresses these lean characteristics

Proof of Need Survey

While the predictable output survey addresses characteristics of the office methods and processes, the Proof of Need Survey relates to the work of the i ndividual employee.

A lean office is an office where the employee:

- Knows the standards of service expected in his area
- Works with well documented and regularly updated processes
- Can easily be replaced with someone not familiar with his work, because of available documented processes
- Performs little overtime
- Can easily adapt to additional influx of work
- Is not replaced with temporary outside help when temporarily gone
- Is experiencing relatively low stress

These elements of a lean office are addressed in the questions of the Proof of Need Survey as shown in Fig. 2.

On a scale from 1 to 5 rate the following statements (1: disagree,, 5: 100% agree)					
	1	2	3	4	5
1. I know the standards of service expected in my area.					
2. The processes I work on are well documented and updated.					
3. Someone not familiar with my work can easily do my job with little or no training due to the availability of a documented process.					
4 I work little or no overtime.					
5. When there is an additional influx of work, I can easily adapt and get it done.					
6. When I am gone, there is no temporary help assigned to my duties.					
7. The stress level for me is low.					

Fig. 2. Proof of Need Survey

Adapted from "Proof of Need Survey", originated by GDC Total Business Solutions and published by MCS Media, Inc 2003.

Lean Assessment Profile Survey

Lean companies are organizations that are in control of the processes which the workers use to perform their jobs; that emphasize cross training and ensure level loading; and that have a reasonable number of generalists, rather than specialists. This is evaluated in the Lean Assessment Profile Survey as shown in Fig. 3.

On a scale from 1 to 5 rate the following statements (1: disagree,, 5: 100% agree)					
	1	2	3	4	5
1. I feel that the organization, rather than the employee, is in control of the process I use to do my work.					
2. If, because of immediate and extended need, you are called to perform the work of another employee, you believe you can do this work. Which job(s) are you able to do?___(use space below)_____ Have you done it in the past?_____ Describe that job._(use space below)_____					
3. The company has written procedures on how to do all jobs.					
4. I believe that everybody has an equal amount of work.					
5. I am always very busy at work.					
6. I consider myself a generalist.					

Fig. 3. Lean Assessment Profile Survey

Adapted from "Lean Assessment Profile Interview", originated by GDC Total Business Solutions and published by MCS Media, Inc 2003

Management Self Assessment Survey

This survey is designed to be filled out by all managers. Answers to this survey can be contrasted with answers given on the first three surveys.

In a lean office one expects that:

- The manager is satisfied with the productivity of the office
- The stress level is reasonably low
- The manager can easily adapt to a sudden influx of work
- The office can easily operate without overtime
- The processes and organizational knowledge can easily be transferred because of existing procedures that are easily accessible
- The metrics that are in place help the managers understand where they are

- There are quick adapters to change

The Management Self Assessment Survey of Fig. 4 addresses these characteristics.

On a scale from 1 to 5 rate the following statements (1: disagree,, 5: 100% agree)	1	2	3	4	5
1. I am satisfied with the productivity in the office area.					
2. The stress level is not high in my office.					
3. I can easily adapt to an influx of work.					
4. I can operate without overtime or temporary help.					
5. The members are satisfied with my level of service.					
6. Most of my processes and organizational knowledge are easily transferred amongst the group (cross training).					
7. We have process procedures and they are accessible to all.					
8. We have standards of service in the organization.					
9. I have metrics in place to understand where we are.					
10. We have quick adapters to change					

Fig. 4. Management Self Assessment Survey

Adapted from "Management Self Assessment Survey", originated by GDC Total Business Solutions and published by MCS Media, Inc 2003

Based on employees' responses to each question of the survey, an average score can be calculated. These average scores can then be used to calculate the overall average score for each survey. Both individual and overall scores need to be scrutinized and analyzed. The higher the survey scores are, the leaner the company is. Scores between 4 and 5 are highly satisfactory scores. A score between 3 and 4 indicates that further improvements towards lean can be made with a reasonable effort from both management and office workers. They also hint that office personnel might be interested in further improving the operations of the office, since they are aware of its shortfalls. A score below 3 reveals major problems that need to be addressed. These problems need to be identified and corrected to bring the company on its journey towards lean.

Capturing Lean Principles of Work Place and Office Operational Procedures

Whether it is an office or a manufacturing floor, a workplace needs to be organized. A work area should be laid out properly and standardized work procedures followed so that all employees can perform their jobs in the most efficient manner. If not, some type of non-value added activity could be identified. Hence, all employees ought to perform their jobs using the three principles of a lean work place: a workplace that is organized, that is properly laid out, and that has standardized work procedures.

Workplace Organization

Workplace organization is defined as a safe, clean, neat arrangement of the workplace. One must provide for a specific location for everything that is needed and we must eliminate anything that is not required to do the job. The principles used for the organization of the work place are the "5 S's". The 5 S programme was initially introduced in Japan and represent five Japanese words that relate to housekeeping (Seiri for Sort), organizing (Seiton for Set in Order), cleaning (Seisou for Shine), maintaining (Seiketsu for Standardize) and sustaining a clean workplace (Shitsuke for Sustain). This programme is a deceptively simple system, yet is very powerful.

Sort what is needed and what is not needed. What is not needed must be eliminated from the workplace. When you are in doubt, throw it out. When implementing this principle you will get rid of excess waste, thus gaining significant space.

Set in order what must be kept. Make what is kept visible and self-explanatory, so everyone knows where everything goes. There must be a designated place for everything and everything must be set in its place. Use an appropriate and logical filing system for your paper work and organize your inventory to accomplish this.

Scrub and Shine everything that remains. Like you clean equipment and tools, clean the workplace and keep it shining.

This leads to **Standardization.** Standardization requires discipline, sticking to the rules of organization and making these rules a habit. Set up some standardized procedures to sort and straighten in a timely fashion.

Sustain, through self-discipline, an organized workplace to avoid future problems. Do not allow yourself to fall back into old habits. You may want to use visuals to sustain the 5 S programme, such as label filing cabinets, restrict the space of labeled inventory areas, etc.

This 5 S system is a powerful system that companies around the world are using to eliminate waste, dirt, clutter, inefficiency and other stumbling blocks to excellence.

Both the company and the workers benefit from a good 5 S programme. Workers find they are working in a more pleasant work environment and find their jobs more satisfying. This gives them more pride in the workplace and generates a positive mental attitude. Their jobs become easier to execute because the procedures make sense. The bottom line is that the workers are spending less time on tasks and are able to perform these tasks to perfection. The company will experience improved maintenance and increased work quality. These generate cost reductions and increased profitability. It ultimately leads to increased customer satisfaction.

Use the survey in Fig. 5 to assess your workplace organization.

On a scale from 1 to 5 rate the following statements (1: disagree,, 5: 100% agree)					
	1	2	3	4	5
Sort					
1. There is no waste or clutter in our office.					
2. All we have is necessary to do our job					
Set in Order					
3. There are sufficient labels to identify the location of all necessary items we need to do our job.					
4. Similar items are located together. I always immediately find what I need.					
Scrub and Shine					
5. Management encourages us to keep our work area clean.					
6. We keep our work area clean.					
Standardize					
7. We sort and straighten out our work area on a regular basis.					
8. Time is allocated by management to check and organize our files.					
Sustain					
9. I have self discipline to sustain order in my work area.					
10. I will not need help and will not fall back into bad habits.					

Fig. 5. Work Place Organization Survey

The higher the organizational score is for the Work Place Organization Survey, the leaner the company is. A score of 4 and above is desirable.

Standardized Work

The workplace principle of standardized work requires that operations be safely carried out with all tasks organized in the best-known sequence and by using the most efficient and effective combination of resources. Resources include, but are not limited to people, materials, methods and machines. In other words, the way all operators are performing their tasks must be standardized. This implies that the best way to perform a task must be determined. In determining the best way, one must focus on eliminating non-value-added tasks, such as motion, waiting and repetition. Once this best method is determined all operators involved in performing the tasks must be trained. This leads to standardized work.

Standardized work implies standardized work tools. Some of these tools are:

- Time observation sheets
- Flow diagrams
- Standard work sheets
- Standard work layout or work instructions
- Standard inspection sheets
- Standard visual control

Proper Layout

A lean office layout is one that has an open-cell orientation that promotes good workflow, visibility of all workers that leads to immediate flow of information and feedback amongst workers. The open-cell layout promotes lean operations through:

- Level loading or balancing of work, temporary re-assignment of work as the demand of certain activities varies
- Sharing of work
- Good communications amongst various workers
- Flexibility in managing
- Pulling the work through the office when work is needed

Office Operational Procedures

Just like waste in production flows are analyzed and identified via the value stream mapping, this tool can also be used to identify waste in operational procedures performed in the office.

Value stream mapping is a process utilized to steer from a current inefficient operational procedure to a future lean procedure. The process of value stream mapping begins by documenting the flows of the existing operations in a "current state" map. Analyzing the current state map and applying lean principles result in the "future state" map. A value stream map is a visual representation of the operations path, documenting flow of activities and information, following a procedure's path from beginning to end, and drawing a visual representation of each activity and its information flow. The map is normally drawn by hand, by following the process from its beginning until it is completed. The map includes both activity flows and information flows. The value stream maps of major office activities allow managers and workers to identify wastes in processes, so they can focus on change to eliminate the wastes.

Some main office operational procedures that can be mapped and analyzed include:

- Procedures for making reservations
- Procedures for generating newsletters and brochures
- Procedures for developing the yearly budget
- Procedures for preparing the annual reports
- Procedures for viewing and analyzing operations
- Procedures for dealing with customer complaints
- Procedures for ordering supplies

All four principles of the workplace organization, standardized work, layout, and office operational procedures can be captured in a company/office specific score card. This is illustrated for a maintenance office in the implementation section of this paper.

Evaluation of historical metrics of the company

When developing metrics for assessing the performance of an office or the business as a whole it is important that these metrics are not company specific, but rather industry specific. Industry specific metrics can be used for benchmarking purposes and are global metrics that give the analyst a "compare and contrast" opportunity when analyzing the numbers.

Some of these metrics could be: historical cost of operations; cost of operations per unit output, historical cost of operations versus growth; extent of the execution of the business plan; budget versus actual expenditures; execution of the business plan, versus budget and versus actual expenditures; metrics related to customer satisfaction; business performance data published by the industry; satisfactory cash flow; and many others.

Though the results of the interviews and surveys are highly subjective in nature, the analysis of the metrics is not. For a company to be lean the outcome of all areas of this three-step methodology must be positive. If it is not positive, the company must develop a programme to steer itself onto a journey to become lean.

Application and implementation

This methodology has been applied to a multiple location Time Share Company that will be referred to as TSC. This application involved an initial analysis of its main office operations and three of its multiple time-share locations in Mexico. Based on the request of the Board of Directors specific attention was drawn towards improving maintenance management at the three locations. These locations are referred to in this paper as Location A, Location B, and Location C.

The Main Office

The main office has 6 employees: the president, an administrative assistant, a bookkeeper/member services person, the reservations manager, and two employees for making reservations.

The Surveys

The overall average scores for the four surveys are summarized in Table 1.

Table I: Survey Score Summaries

Type of Survey	# of Responses	Average Score
Predictable Output Survey	6	3.36
Proof of Need Survey	6	4.55
Lean Assessment Survey	6	4.06
Management Self Assessment Survey	2	4.55
Overall Lean Office Score		4.13
Weighted Overall Lean Office Score		4.05

In summary the interviews with all employees consistently and without exception indicate that all employees share knowledge of each others processes; that the processes have been defined by the organization with some input from the employees; that the employees have been cross-trained in each others job; that the

employees consider themselves more as generalists, rather than specialists; and the employees believe that the workload amongst themselves is equal. These are some distinct characteristics of a lean office environment.

However, a closer analysis of the Predictable Output Survey (Table 2) reveals some concerns. The overall average score of 3.36 is due to four average scores that are equal to or less than 3.50. TSC does not have meetings that focus on the processes (average score of 1.33). Two out of 6 employees indicated that they are not able to make improvements/changes, based on a systematic process and the other four respondents partially agreed (score of 4) with the statement that they are able to make improvements/changes based on a systematic process. This resulted in an average score of 3.00. These two areas need to be looked into if improvements are desirable. Additionally, with an average score of 3.50 for "most of my time is spent on value-added work", there is a need to evaluate for possible waste in the operations of the office.

Table 2: Predictable Output Survey Results

	Average Score
1. There are standard methods and processes that ensure the quality of work for each employee or work assignment.	4.34
2. The methods and processes are continually improved upon.	3.50
3. The methods and processes are made visible and are easily Accessible.	3.83
4. The methods and processes are documented.	4.00
5. We have meetings that focus on the processes.	1.33
6. Employees are able to make improvements/ changes, based on a systematic process.	3.00
7. Most of my time is spent on value-added work.	3.50
Average Score (6 respondents)	3.36

The Lean Assessment Profile Survey scores are summarized in Table 3. Even though the average score of 4.06 is very satisfactory, the detailed analysis indicates one area of concern. In answering the question on whether they were always very busy at work, they all revealed that there were patterns of business during the day. In the future, if the company feels that there is a need for re-alignment of personnel, these patterns ought to be studied

Capturing Lean Principles of Workplace and Office Operational Procedures

The average Organization Score of 4.2 is highly satisfactory. Its breakdown is shown in Table 4.

Table 3: Lean Assessment Profile Survey Results

	Average Score
1. I feel that the organization is in control of the process I use to do my work.	4.50
2. If, because of immediate and extended need, you are called to perform the work of another employee, you believe you can do this work. Which job(s) are you able to do?___(use space below)_ Have you done it in the past?_____ Describe that job (use space below)_____	4.33
3. The company has written procedures on how to do all jobs.	3.67
4. I believe that everybody has an equal amount of work.	4.67
5. I am always very busy at work.	3.00
6. I consider myself a generalist.	4.17
Average Score (6 responses)	4.06

Table 4: Workplace Organization Score

	Average Score
Sort	
1. There is no waste or clutter in our office.	5
2. All we have is necessary to do our job.	5
Set in Order	
1. There are sufficient labels to identify the location of all necessary items we need to do our job.	3
2. Similar Items are located together. I always immediately find what I need.	4
Scrub and Shine	
1. Management encourages us to keep our work area clean.	5
2. We keep our work area clean.	5
Standardize	
1. We sort and straighten out our work area on a regular basis.	4
2. Time is allocated by management to check and organize our files.	1
Sustain	
1. I have self discipline to sustain order in my work area.	5
2. I will not need help and will not fall back into bad habits.	5
Average Organizational Score (4 employees)	4.20
Observed Organizational Score (by this reviewer)	3.80

The workplace organization of The Time Share Company exhibits all of the 5S lean principles (Sort, Straighten, Scrub/Shine, Spread and Standardize). As you walk in this office you immediately notice that what is needed is sorted, organized and given a place. Most of what is

needed and kept is visible and self-explanatory; so employees know where things go. The office is clean and exhibits little clutter. This organizational discipline is spread to all areas of the office because of its open layout. This has lead to standardization that requires discipline, sticking to the rules and making the rules a habit.

The principle of standardized work at The Time Share Company manifests itself when one looks at the procedures that have been established over the years to do the major activities of this office. Major activities have been redefined over the years and computer technology has been introduced to perform these activities in the most optimal way.

Many processes are thus computer driven, which makes cross training easy and many of the activities/ processes are documented and are easily accessible and known by all members of the office.

The layout of The Time Share Company is conducive to lean operations because it exhibits many of the necessary lean characteristics. The various departments are a one opencell that promotes good workflow, visibility of all workers, immediate flow of information and feedback amongst workers. This opencell layout promotes lean operations through level loading or balancing of work, temporarily reassigning of work as the demand of certain activities varies; sharing of work; good communications amongst various workers; flexibility in managing; and pulling the work through the office when work is needed.

Though the layout is conducive to lean operations, it seemed to the researcher that the space was slightly excessive.

Historical Metrics of this company

A dozen metrics were considered appropriate for evaluation. The following major ones are discussed in this paper:

1. Maintenance Fee History.
2. Improvements and Reconstruction.
3. Consumer Satisfaction Index (CSI) from Interval International.
4. RCI Recognition Program Scores.
5. Membership/guests questionnaires and follow up, listening to the voice of the customer.
6. Business Plan.
7. Business Plan versus execution of Business Plan.

Maintenance Fee History

This company is in its 23rd year of operation.

Since its inception, maintenance fee for a one bedroom and a twobedroom unit has increased at an average annual rate of 3.875%. However, after the company ceased expanding and became member controlled the average annual rate increase has been approximately 1.2% for both the onebedroom and twobedroom units.

A quick review of time share sales posted on the TUG (Timeshare Users Group) website (www.tugz.net) reveals that the maintenance fees of this timeshare company rank significantly below the industry average.

Major Improvements and Reconstruction

Above reasonable maintenance fees have not only provided funding for the maintenance and operations at the various locations and the management of the main office, but also enabled the funding of significant improvements at various resort locations. Some of these improvements have increased the value, the comfort and the quality of the facilities; others have reduced certain operational expenses. Here is a list of some of these major improvements/additions: installation of a water softening system; installation of electrical transformers allowing the company to buy electricity at a commercial rate (in light of the high and ever increasing electrical rate this investment will pay off in relatively lower electrical cost); installation of hurricane blinds; a new roof of high quality synthetic tiles and improvement of roof foundation have improved the appearance and the quality of the condos; solar energy panels allowing to heat a swimming pool at a reduced cost; retiling of two facilities increased the value and the overall quality of the property; upon request from the membership intercom phones were installed in all units in 2004; securing of the foundation and wall alongside the hill at one resort location; installation of a ten people new Jacuzzi; installation of a new elevator in one of its resorts; and many others. Besides these specific significant reconstructions and improvements The Time Share Company has also improved the appearance and quality of all units: upgrading the quality of furnishings and decorations; creating a more pleasant interior; improving the quality of many appliances, dining ware, and kitchen accessories. The grounds are cleaner and more charming. Windows have been sealed and, where appropriate, railings have been installed for the safety of the vacationers.

Consumer Satisfaction Index (CSI) from Interval International

Interval International compiles consumer satisfaction scores from exchange guests who stay at their resorts. To better understand the scores, the reader must be aware of the fact that TSC has mostly four star resorts and that Interval International chooses to exchange into TSC's resorts members who have memberships in five star and five star crown resorts. Naturally, some of these members are going to be disappointed when they exchange into a four star resort. It also should be noted that Interval International does not consistently supply this company with their CSI index on a continuous basis.

The overall CSI score is based on four major criteria: vacation area (accessibility, attractions, activities and restaurant), resort (location, facilities, amenities and organized activities), unit (size, view, kitchen & supplies and cleanliness) and guest service (staff hospitality, check in/check out, maintenance and housekeeping). The average yearly CIS scores as of 10/2002 and 12/2004 are shown in table 5 for four resort locations that are used for exchange purposes

Table 5: Average Yearly CSI Scores from II

Location:	Vacation Area		Resort		Unit		Guest Service		Overall CSI	
	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004
Location I	84	93	75	89	92	95	93	95	86	93
Location II	77	79	67	68	86	85	88	88	80	80
Location III	69	82	73	90	82	95	88	97	78	92
Location IV	81	90	77	86	91	92	92	92	85	90
Industry Average									86	86

Since 2002 TSC has significantly improved the scores of three of the above listed four resorts. As of October 2002 none of their II (Interval International) resorts had a CIS score higher than the industry average CIS score of 86. As a result of major efforts in three of these four resorts they have improved these scores for 2004 to over 90, significantly above the industry average of 86.

They still have work to do in one of their resorts, where their score has not changed and is still significantly below the industry wide CIS average.

RCI Recognition Programme

In 1992 RCI launched a Resort Recognition Programme, whereby RCI recognizes those resorts that consistently exceed high standards of product quality and service. The programme was revised in 2002. Since 2002, RCI awards three types of awards: the Gold Crown Award (GC award), the Resort of International Distinction Award (RID) and the Hospitality Award (HOSP). As of August 2003 and August 2004 the yearly scores for five of their resorts are shown in Table 6.

Table 6: Yearly Average RCI Scores
(5: very satisfied, 4: satisfied, 3: neither satisfied/Dissatisfied, 2: dissatisfied, 1: very dissatisfied)

	Check I/O		Resort Hosp.		Resort Maint.		Unit Maint.		Unit Hskp	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Location I	4.6	4.2	4.6	4.3	4.7	4.1	4.5	3.8	4.6	4.1
Location II	4.5	4.0	4.7	4.2	4.6	4.3	4.4	3.7	4.6	4.1
Location III	4.8	4.7	4.8	4.7	4.8	4.6	4.3	4.3	4.8	4.5
Location IV	4.1	4.5	4.8	4.5	5.0	4.5	4.6	4.3	5.0	4.6
Location V	5.0	4.5	5.0	4.5	4.5	4.5	4.7	4.2	5.0	4.6
Latin/South American Market	4.3	4.1	4.4	4.3	4.5	4.3	4.1	3.9	4.4	4.3
GC Threshold	4.0	4.0	4.2	4.2	4.0	4.0	4.2	4.2	4.0	4.0
RID Threshold	3.9	3.9	3.9	3.9	3.7	3.7	3.9	3.9	3.7	3.7
HOSP Threshold	4.0	4.0	4.2	4.2	3.2	3.2	3.2	3.2	3.2	3.2

As part of the award process, all resorts that meet or exceed the minimum comment card thresholds are also evaluated on resort facilities criteria. These include resort amenities, guest services, unit amenities/interiors and resort maintenance.

As a result of the overall evaluation two of their resorts were downgraded in 2003 from RCI's Gold Crown to RCI Resorts of International Distinction. According to a November 12, 2003 letter from RCI to their main office the downgrading was specifically attributed to the lack of phones in the units. In a letter received on February 10, 2005, one of their resorts was awarded the RCI Gold Crown Award for 2005. All other resorts received the RCI Resort of International Distinction Award for 2005.

Membership/Guests Questionnaires

The company receives, analyzes and follows up with all comments received from vacationers. This researcher has read all positive comments and additional suggestions/complaints submitted by the members and guests who have visited their resorts for the last seven years.

According to the summaries of the comments on the membership/guests questionnaires the people managing and serving at the various locations are just great. This is best summarized by a statement made by one guest vacationer of Holiday Systems International: "Simply put, I've been in Timeshare business for over 7 years and could use many people just like your staff at ..... They are great people!" (October 12, 1998).

Through reviewing the membership/guests questionnaires and reading all letters sent to the office, office management stays in tune to the needs of its membership and is able to take proper action when appropriate. Accordingly, management of The Time Share Company has shown a great commitment to its membership and is committed to continuous improvement of the club and its assets.

The Business Plan

In order for the company to judge and approve major projects they need to be aware of the history of past complaints. This history will help them make better judgments when developing a business plan. Based on a sevenyear history of complaints and suggestions made by its members and exchange members, projects and their priorities can perhaps be grouped as follows:

1. Group 1 contains projects that relate to safety and security issues. If these issues are not immediately taken care of when the complaint is presented, they ought to become a project of priority 1.
2. Group 2 consists of projects that relate to providing minimum resort amenities as is expected of this type of resort (they are recognized as a four star resort). This group of projects should also address maintaining these amenities at an acceptable quality level, thus giving its users a reasonable comfort that can be expected of a four star resort. If some of these projects have been neglected over a long period of time, they should be considered as priority #1 projects and need to be attended as soon as possible. Otherwise they can be considered as priority #2 projects.
3. Group 3 consists of projects that would improve on the generally accepted quality level of this type of resort and its amenities. We may consider these projects necessary in order to maintain this company's acceptability in the exchange community to which its members belong.

TSC has not done a satisfactory job in prioritizing projects, based on customer complaints and suggestions. This perhaps explains some of the low CSI scores for location II (see Table 5). Because the Board of Directors must approve major projects it is recommended that the office summarize all customers' complaints for their review.

Table 7: The Score Card (Scale 1 through 5)

	Location A	Location B	Location C
Workplace Organization: the 5 S program			
Office Layout and Organization	4	5	1
Office Cleanliness	5	5 excellent	3 implement 5Ss
Standardized Work Forms:			
Inspection Forms	3	5	4
Work Schedules	2 some made attempt	3 in file cabinet	2 some attempt made
Work Orders	3 could use computer as compared to B	4 could use computer	3 could use computer as compared to B
Operational Procedures:			
Work Generation/ Execution	3 were not shown	5	3 were not shown
Inventory/Tools Control	3 as compared to B	5	3 as compared to B
Control:			
Scheduling and Control	3 some attempt made	5 in file cabinet	3 some attempt made
Computer System	1 non existing	1 non existing	1 non existing
Visual Controls	1 non existing	1 non existing	1 non existing
Total Score (out of 50 points) :	28	39	24
Average Maintenance Score out of 5	2.8	3.9	2.4

Business Plan versus Execution of Business Plan

Part of a business plan is to identify projects that need to be executed in the coming year.

Based on this plan a budget is generated and TSC sets its maintenance fees. Any discrepancies between the plan and its execution need to be addressed in the next business plan. This is not addressed in TSC's business plan.

In conclusion, because of the results of the surveys, workplace organization, office operational procedures, its continuous improvement policy, reasonable maintenance fees and good member and guest satisfaction ratings, the management approach of TSC can be used to a certain extent as a benchmark for similar multilocation timeshare companies. As indicated in this analysis, there are however areas where this company can improve on.

In the second part of the analysis, and upon request of its Board of Directors, the maintenance management function at three of its resorts was analyzed.

Maintenance Management Function

As for the main office, an evaluation of Maintenance Management includes an assessment of the workplace organization (the 5S programme), standardized work forms, office operational procedures and control. A scorecard capturing maintenance specific characteristics was developed for three locations. The results of these scores are shown in Table 7.

Workplace Organization: The 5S Programme

Workplace organization is excellent in location B, but is extremely poor in location C, with an average score of 2 out of 5. Extremely poor workplace organization is indicative of poor maintenance management. Location C needs to implement the 5S programme first before it can implement and properly execute various aspects of Total Productive Maintenance, such as the scheduling and control of routine and preventive maintenance. This can be accomplished through proper training. It was suggested that the maintenance supervisor of location B execute this training.

Standardized Work Forms and Operational Procedures

All locations have some sort of work order forms and inspection forms of their own. It is suggested to consolidate these forms and to generate a set of forms that must be used at all locations. The work order generation forms and inspection forms of location B can serve as a blue print for this endeavour. It is the responsibility of the general manager of all resorts to oversee this development. Following common forms must be developed for all work done by their own maintenance crew: Condo Inspection Form, Inspection Form for Grounds and other Areas, Hot Water Heater Inspection Form, Soft Water System Inspection Form, Work Order Generation Forms (with procedure for use), Materials/Inventory Control Forms (with procedure for use).

Control

A total productive Routine Maintenance (RM) and Preventive Maintenance (PM) system is a system that is both efficient and effective. An efficient maintenance system is one that has all the proper tools for timely execution of all maintenance requirements. An effective maintenance system is a system that can be managed with minimum effort of control. RM and PM require a timely execution of inspections, the generation of work orders, the scheduling of maintenance activities and the timely control of its execution.

In developing a productive maintenance system one must aim at minimizing paper work and at generating visual controls. The paper work and visual controls are part of the communication system of a total productive maintenance system. Effective inspection forms are compact, yet comprehensive forms that use a coding system to communicate work to be scheduled. Do not create these files to be filed for a long period of time, rather they ought to be created to be used to generate work schedules.

Routine and preventive maintenance systems (RM or PM) with visual controls significantly improve the scheduling and the control of routine inspections. Without the presence of visual controls, a maintenance supervisor spends an enormous amount of time going through files, data forms, past work done and other documents to ensure the timely execution of all future inspections, PM and RM activities. This wasted time can better be spent supervising and improving the maintenance department. Visual controls were lacking at all locations. Sixteen charts have now been developed for all three locations. A sample example is shown in Fig. 6.

These visual control charts reflect all of the following:

1. When preventive maintenance needs to be done (shaded area on the template, with yellow work to be done by contracted workers, green work to be done by company workers).
2. When preventive maintenance is performed (an X mark is placed on the chart by the supervisor).
3. When additional work is performed due to breakdown/problems (a * mark is placed on the chart by the supervisor).

Over time, the company must analyze the third item, to come to a consensus about the frequency of Preventive and Routine Maintenance. At the present time, different frequencies are implemented at their various locations. Consequently, visual controls are dynamic in nature and need updating from time to time. When properly trained, the maintenance supervisors can easily perform this task. Because of the continuous need to view and to update these visuals, they are most effective when used on a computer system. Therefore, it is necessary for all locations to have a basic computer and colour printer in order to help both maintenance and management perform their jobs in a more effective way.

At the time of this research there wasn't a company computer at any of these three locations. The following are the advantages for having a computer system:

- It will bring the company into the 21st century, because the internet has become a standard platform for global business.
- It will reduce TSC's communication costs (at the present time communications were mostly done via postage, DHL, fax and telephone system at a large expense) and easily pay for itself within one year.
- It will give the company more overall control over the resorts because of a more timely access to information (via instantaneous file and information transfers).
- It will replace the company's old communication infrastructure and processes by a real time communication system.
- It will give them real time maintenance interaction.
- It will enable maintenance to better control the execution of scheduled routine and preventive maintenance work, because of the visual controls a computer will give them.
- It will reduce clutter and space requirement in the maintenance areas because forms and maintenance information can be kept in computer files.
- It will allow the maintenance supervisors to generate and follow up on work orders via a computer rather than by hand.
- It will allow the maintenance supervisors to have more time to supervise.
- It will also allow the managers to do their jobs in a more effective way.

This prompted the Board of Directors of this company to introduce the necessary hardware and training of their personnel.

Conclusions

Although it seems that a lot of work is involved in creating lean operations, the truth is that the more you prepare and understand, the smoother and more efficient your lean launch will be.

If we are measuring the right things, in the right way, and these things drive positive change, then we automatically have a legup on the competition. With so many companies going out of business every day, it is easy to see the benefits of taking charge of the things we have the ability to control and improve.

Don't forget about customer and supplier surveys too. These can provide yet another dimension to our understanding and improvement of the business. As mentioned in the introduction, "perception is reality," and every perception we can change for the better, drives us towards success and profitability.

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Feature

Managing Stress: An Integrative Approach

Daisy Chauhan

Stress is an all-pervasive phenomenon of life that affects different people in different ways. In this paper an attempt has been made to provide an integrated approach to managing stress, wherein it has been suggested that each individual has the choice to adopt an action-oriented approach or an avoidance approach to a situation that is perceived to be stressful. Again, in deciding to take an action-oriented approach one has the choice among four different approaches of being Proactive, Reactive, Defensive or Fault-finding. Thus a holistic and integrated approach of coping with stress would depend on the realistic perception, interpretation and appraisal of the situation causing stress.

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Stress has become part of our daily life, with the media like television, radio, newspaper etc. also highlighting the effects of stress on the health and well being of individuals and also suggesting different techniques to cope with stress. In spite of the widespread awareness about stress, there is lack of consensus on the definition of "stress". This could be attributed to the fact that stress has different connotations to different people in various fields.

Thus, the word "stress" can be considered to be an abstract term which could mean different things, in the same way as happiness, success, failure etc. Hans Selye, a pioneer in the field of stress has defined it as "the non-specific response of the body to any demand made upon it" (Selye, 1974), while Lazarus & Folkamn (1984) define it as "a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well being." Both these definitions clearly bring out the fact that demands do not necessarily have harmful effects. Rather, harmful effects result from a person's perception and interpretation of those demands. But what is interesting to note is that in describing stress in their life, many people see it as an excess of demands over resources and these demands seem to emanate from the outside. Even if we accept this there is no denying that stress management is the ability to maintain control over oneself when situations, people and events make excessive demands.

However, stress may also be experienced due to pressures from within, from our beliefs, attitudes and expectations from ourselves and others, from our habits, behaviour and personality. Although we may not be aware of many of our attitudes, we tend to be controlled by them. They filter as well as influence our perceptions, allowing us to experience only what we want to or believe we will experience. This is very aptly brought out in the saying "Life is 10% of what really happens and 90% is how you react." Thus it is our attitude to an event that matters more than the event itself.

As Blair Justice (1987) states, "Our attitudes... toward the very subject of stress can influence our reactions when we are in trying situations. Our physiological responses will be considerably less intense if we see stress as an inevitable part of life and a challenge rather than something that is awful and must be avoided".

Extending this further, we are at times not experiencing total satisfaction in certain areas of our lives because we unconsciously assume or believe that we cannot or will not. The Rational Emotive Therapy put forth by Albert Ellis contends that we live by assumptions or beliefs which may be irrational, which affect our opinions and expectations ourselves and others and the world in general. Ellis cites a number of basic and common irrational beliefs that most of us have. They broadly relate to: (1) ourselves and would be something like, "I must always be right, outstanding, pleasing, accepted and loved – if I am not, then it is awful, unbearable and I'm no good"; (2) assumptions which relate to other people when we expect "Other people must do things our way and give us what we want" and (3) our view of what life should be like - "Life must be easy and without problems and give us our due". All these assumptions, beliefs and expectations bring with them anxiety, and if not fulfilled, certain negative consequences.

Effects of stress

The effect of stress on health can be understood when we consider health as defined by the World Health Organisation, which is "the presence of physical and emotional well-being in the individual." Though stress adversely affects the well being of an individual, does it constitute "illness"? It is very difficult to link stress clearly as a causal agent in illness but there are a number of areas where it is 'implicated'. In other conditions we know that stress exacerbates the problem, even if, by itself, it does not cause it. Experts estimate that between 50 and 80 per cent of episodes of illness are stress related (Charlesworth & Nathan, 1984; Pelletier, 1977). Stress contributes to illness in four ways:–

1. By imposing long-term wear and tear on the body and mind and thereby reducing resistance to disease.
2. By directly precipitating an illness such as a heart attack or tension headache.
3. By aggravating an existing illness such as increased arthritic pain.
4. By precipitating unhealthy or even illness-generating coping habits such as smoking, alcohol abuse, over eating or sleep deprivation.

The effect of stress on individuals depends on a number of factors. Here we would like to deal with three factors – the stressors themselves, the emotional state of the individual and the lifestyle of the person as detailed below:

Stressors

The impact of stress on an individual is significantly influenced by the following aspects:

- Duration: short job interview vs dissatisfaction with a job
- Severity: Minor vs major illness
- Predictability: Level of stress would depend on prior knowledge about an event providing scope for planning and preparing vs an unexpected happening
- Controllability: Perception of the extent of control one has over the situation

Some amount of stress is inevitable. It is only when excessive levels of stress are experienced for longer duration, when it is unexpected and when individuals have little control over the situation, that it has a negative impact.

Role of Emotions

Emotions involve a complex interaction between mind, body and behaviour. The biological, behavioural, cognitive and psycho-dynamic perspectives are all concerned with important facets of emotion. The word emotion is derived from the Latin word for "movement", originating from the idea that emotions both guide and goad our actions. Emotion is always in relation to an object, like being angry at something or someone, or being in love with someone, or fearful of something. Emotions arouse us, help organize experience, direct and sustain actions, and communicate actions (Fridja, 1989). Emotions also have been linked with immunocompetence, which refers to the body's ability to defend against a microbial invader. For example, depression has been shown to suppress lymphocyte and T cell activity (Kronfol et. al., 1983; Schleifer et. al., 1989). On the other hand, laughter has been shown to result in proliferation of lymphocytes and natural killer-cell activity.

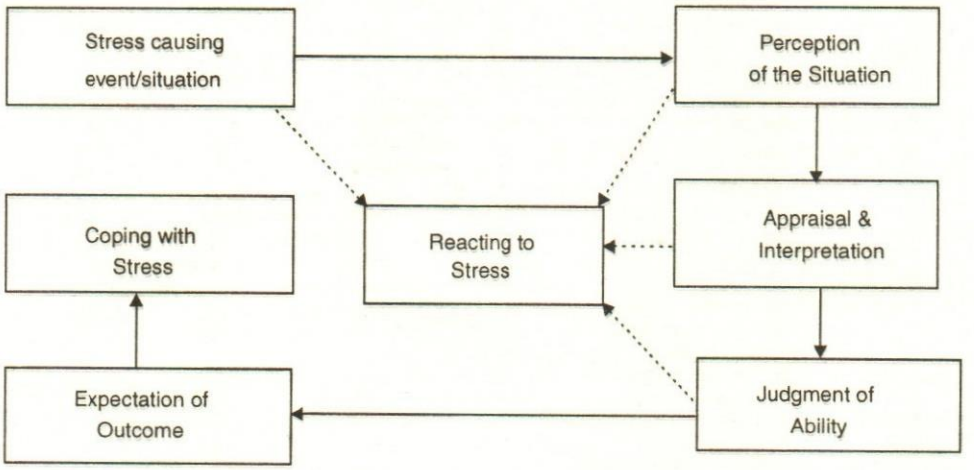

Fig. 1. Reacting to and Coping with Stress

Influence of lifestyle

We need to understand some facts relating to stress and today's lifestyle. These are:–

- The faster pace of life in this century has increased the number of stressors we face.
- Most stressors today are psychological and social rather than physical.
- We have become more sedentary, resulting in less release of energy buildup. Thus to effectively manage stress we need physical action to release energy and tension.

Influence of perception on stress

Our response to stress would depend on our interpretation or on the way we perceive a situation or event. A positive interpretation is stress reducing while a negative interpretation is stress inducing. In the words of Alfred Adler, "We are influenced not by "facts" but by our interpretation of facts." This explains why the same amount of stress affects different individuals differently and produces different responses from the same individual in different situations. Thus under the influence of same pressures some may respond positively, some negatively while others will have no reaction. Our response to stress depends on our perception of the stress causing factors, the interpretation, the belief in our ability to cope with it, and our expectations about the outcome of the whole process. Thus, some people thrive on pressure while others fall apart.

The experience of stress is partly dependent on the individual's ability to cope with demands placed on them and the ability is related to issues of control and support. In the 60s and 70s researchers began to focus on the cognitive and behavioural causes of stress. Thus, our body's stress response is believed to be activated by mental processes, such as the appraisal of situations (e.g. threat/no threat; danger/no danger), our interpretations of events (e.g. good/bad, positive/negative), and our judgement of a situation and about our ability to cope with our problems successfully. Thus, stress can be viewed as a mind-body "psychosomatic" phenomenon.

Stress is thus defined as a psycho-physiological arousal response occurring in the body as a result of a stimulus which becomes a "stressor" by virtue of the cognitive interpretation of the individual. Whether an individual is reacting to stress or is effectively coping with demands depends on a number of variables or the psychological processes taking place within himself/herself as depicted diagrammatically below:

It is very clear from the above that the stimulus (event/situation) itself is not a stressor but an individual's perception, appraisal, interpretation of the situation/event and judgment of his ability to deal with the situation, and finally his expectation of the outcome is what makes it a stressor. It brings us to a very important conclusion that stress is a state of the mind, just like happiness. When viewed in this context, it can be said that though stress cannot be avoided, it can certainly be managed. Moreover, stress can be either positive or negative. A situation can be viewed as a challenge or a threat. When viewed as an opportunity or challenge it can help in realizing one's inner potential and bring out the best in each individual. Thus, a more positive approach to managing stress would be to take the responsibility for one's actions and thereby the consequences.

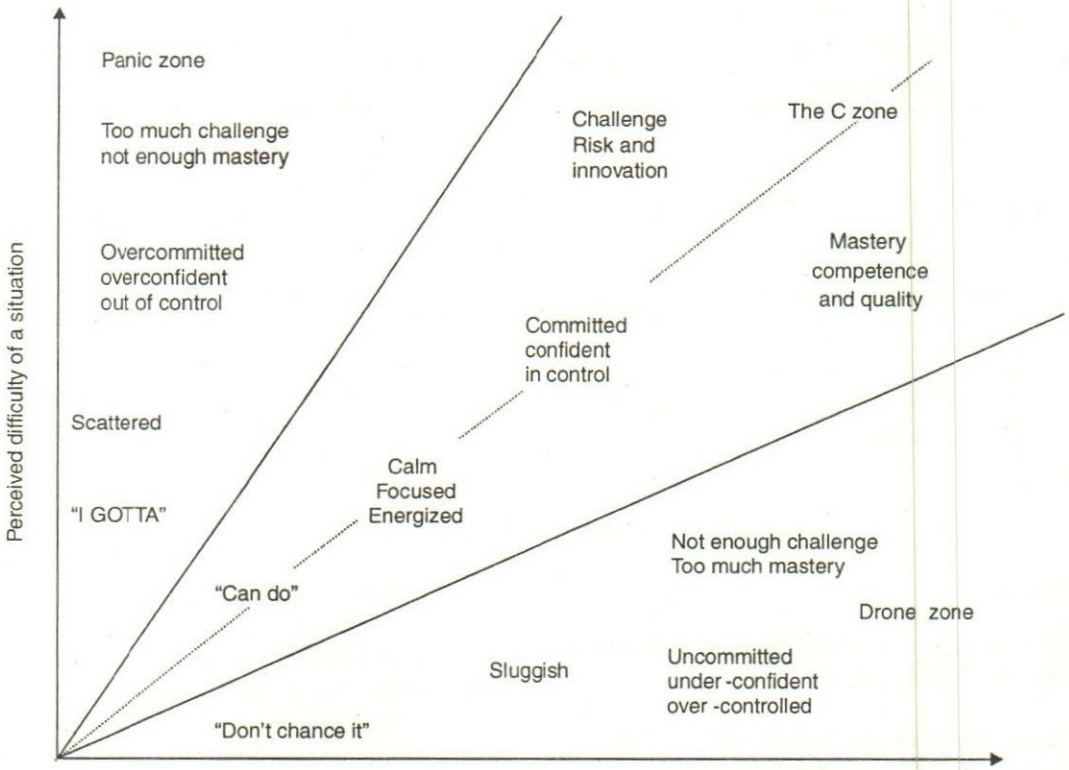

Fig. 2. The Performance Zone Diagram

Personality type and stress

The outcomes of stress or the reactions to stress depends on two main aspects of an individual:—

1. Personality Type
2. Control and Influence

Personality type

People are broadly categorised into personality 'A' and personality 'B' based on their individual characteristics. Type A person is one who is competitive, hard driving, tense, aggressive, preoccupied with deadlines, work-oriented and who has a need to control their environment (Friedman & Rosenman, 1974). Type B is one who doesn't suffer from impatience and time urgency, has no need to impress others with their achievements, is able to work without agitation and relax without guilt. People with type A personalities are therefore likely to experience more stress. Further, under the broad category of 'A' personality are two sub-components (Williams, 1994):

- The achievement striving pattern
- The impatient-irritability pattern

A person who is achievement-oriented focuses on achieving results and is concerned with success. His behaviour is directed in the positive direction. On the other hand the other type is the worrying type and is frustrated and angry. People having the achievement-oriented type 'A' personality are the ones who take a positive approach to the stressors of life and view them as challenges and work towards realising their inner potential, even under adverse conditions. They are generally optimistic and resilient, not allowing setbacks to slow them down. They can usually handle a lot of stress and pressure without falling apart. They actually seem to thrive on pressure.

Type C Pattern

The achievement striving type 'A' is explained as type 'C' by Kriegel and Kriegel (1984). Type 'C' pattern, which is the ideal one, draws some of the best attributes from the type A and type B patterns and adds new elements to meet the challenge head-on for success and vitality. The "C" stands for challenge, confidence and control. The characteristics of type C are:—

- Transcendence: They go beyond their usual level to new heights of personal performance.
- Effortlessness: Their performance flows easily, without special effort or struggle.

- Positive: They are optimistic and confident, thoroughly enjoying what they do.
- Spontaneous: Their thoughts and actions are naturally unified. Choices come easily to them.
- Focused: Their concentration is complete. They are fully engaged with the process, totally involved and fully connected.
- Vital: They feel usually energetic and total joy in what they do and accomplish.

According to Kriegel and Kriegel, the Performance Zone Diagram can be useful in assessing the balance between your perceived difficulty of a challenge and your perceived ability to handle that challenge and thereby thrive under pressure.

Personality differences and vulnerability to stress

Stress has a differential effect on different individuals as no two individuals are identical. While external factors can cause stress, internal factors or individual factors can have more of a moderating influence or effect on stress. These relate to:—

- The condition of the individual
- Conditioning

The condition refers to the internal factors which relate to personality characteristics which are in-born or genetic, which become a person's predisposition to perceive, react and cope with stressors. Conditioning refers to those personality characteristics which develop as a result of the learning or experiences gained on a day-to-day basis. Conditioning can be of two types: (1) unconscious process of conditioning of which we may not even be aware of; (2) a conscious process when one develops certain skills or develop one's cognitive ability to deal with different stressors. Repeated encounters with stress and success in coping with it makes us reflect and logically analyse the whole situation. This process helps us in developing our cognitive ability to cope with stress.

Psychologists are gradually agreeing that learning plays an important role in determining an individual's stress tolerance. Conditioning makes us take stress as a part of our life and we develop an understanding about their transitory nature, thereby learning to cope with the stresses of life. In addition to the conditioning process of coping with stress we also develop certain skills for handling stressful situations. Each time we are able to successfully handle some stress, we develop confidence in the ability to withstand stress and this reduces the negative perception of stress and thereby its negative impact.

Control and Influence

The second aspect which determines our response to stress is the extent to which we believe we can control or influence the environment or events. Based on this aspect, people are said to be having an Internal Locus of Control or an External Locus of Control. Internals are those who feel that they make things happen, while externals are those who feel that things happen to them. Lack of control and influence is a major cause of stress. The more an individual perceives himself to have no or less control over the situation, the more likely it is that he will perceive the situation as threatening and stress inducing and thereby manifest adverse reaction patterns (Chung, 1977). Several studies have examined the buffering effects of perceived control. Researchers have predicted that employees who perceive themselves more in control would experience fewer negative consequences of role stressors than their counterparts, who perceive themselves less in control (Ganster & Fusilier, 1989; Schaubroeck & Merritt, 1997; Tetrick & La Rocco, 1987).

Psychoneuroimmunology (Pni) - The interplay of mind and body

Mind and body have been viewed as two separate entities and modern medicine has been influenced by this dichotomous view of the human propounded by the French philosopher, Rene Decartes. In this regard Decartes writes "His (Rene Decartes) treatise characterized the body as essentially a complete machine and illness as the manifestation of a breakdown in one of the machine's parts. The role of medicine – and ultimately the physician – was to identify and repair the broken part." Thus the diagnosis and treatment is exclusively targeted at a particular organ or body system. As opposed to this the whole person, lifestyle approach to stress is that mind, body and behaviour are closely intertwined (Schafer, 2004). Stress is a physical, chemical or emotional factor that causes wear and tear on the body and mind. It creates imbalance in every bodily system. Psycho-neuro-immunology is a new hybrid, interdisciplinary field of scientific study of this complex mind-body linkage (Booth, 1996, Borysenko & Borysenko, 1983; Lloyd, 1996). Kenneth Pelletier (1994) recently wrote that "Psychoneuroimmunology research opens a new window onto the complex psychological and behavioural factors that influence the onset and course of stress and immune-related diseases. Correlations between high levels of stress and

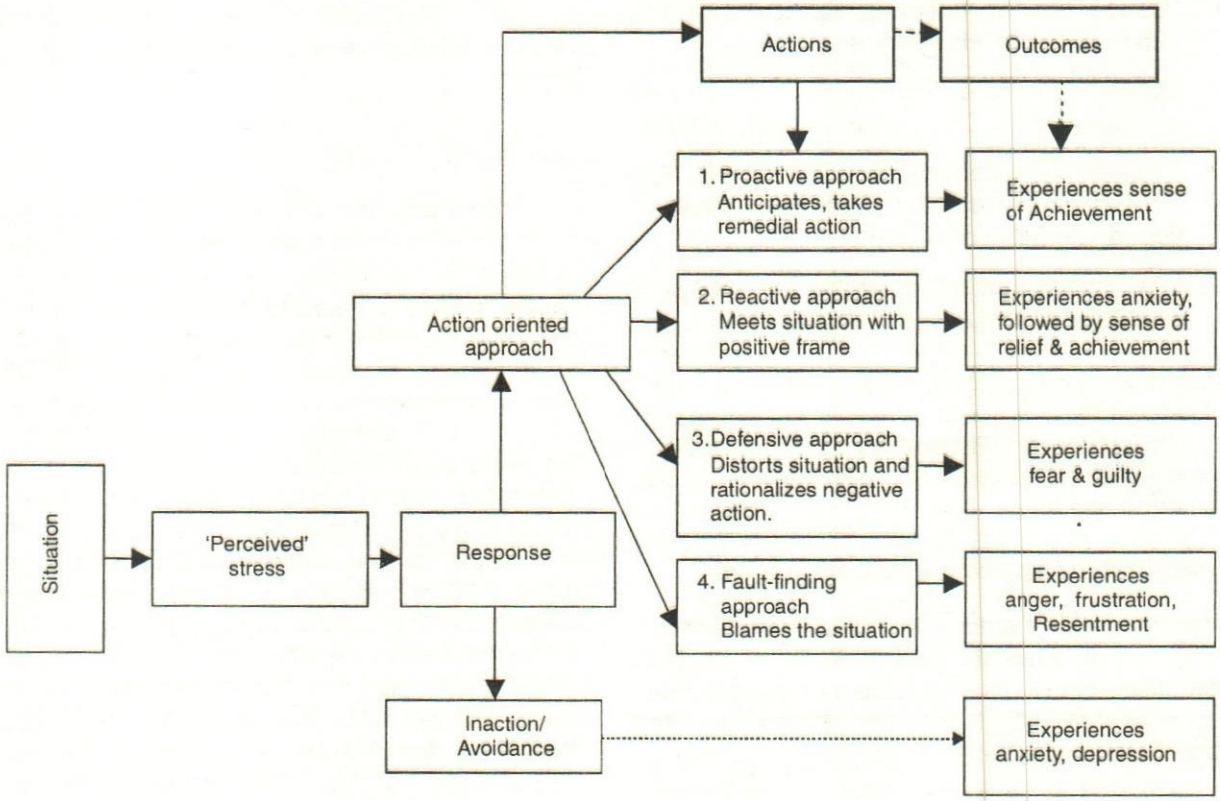

Fig. 3. Model of Stress Management: An Integrative Approach

myriad health problems have been found, including cardiovascular disease, high BP, headaches, back pain, ulcers, anxiety, insomnia, sexual problems, depression, increased accident rates, alcohol and drug abuse, increased susceptibility to infectious disease, and even the common cold."

A considerable and growing body of research shows that stress can suppress the immune response, thereby increasing chances of immune-related illness (Borysenko & Borysenko, 1983; Dantzer &Kelly, 1989; Jemmott & Locke, 1984; Kiecolt-Glaser& Glaser, 1988; Leclere & Weryha, 1989; Pelletier & Herzing, 1988; Rogers, Dubey & Reich, 1979). Though behaviour is not part of stress response itself, it is closely related to it in two ways:

- Mental and physical arousal often gets expressed in behaviour
- Behaviour is used to react to distress, either constructively or destructively.

Managing stress

Stress is also defined as "an adaptive response, moderated by individual differences, that is a consequence of any action, situation or event that places demands on a person" (Ivancevich & Matteson, 1980). When viewed in this context, the onus of managing or coping with stress would lie with the individual and it would be worthwhile to re-examine some of the personality attributes which could moderate the negative influence of stress. People cope swith stress in different ways. Lazarus and Folkman (1984) define coping as 'constant changing cognitive and behavioural efforts to make specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person'. The most effective approach is the positive task-oriented response to deal with the problem at hand. Such an approach is generally adopted by people who are not vulnerable or predisposed to experiencing stress. In vulnerable individuals we are likely to witness anxiety, defensiveness and anger (Taylor, 1983).

We propose an integrative model of coping with stress which brings out the different approaches of dealing with stress and the consequent outcomes of the different approaches. The model explains the whole process of how a situation which is neither positive or negative can

result in both positive and negative experiences (outcomes). As can be seen from the model, if the situation is perceived to be stressful one can respond to this situation either by avoiding it or confronting. Again the action-oriented approach can be in four different ways: (1) Proactive Approach; (2) Reactive Approach; (3) Defensive Approach; and (4) Fault Finding Approach. Thus it is quite clear that for managing stress different options are available to individuals. He or she can choose to respond to the "perceived stress" either by taking an action-oriented approach or can choose to take a passive approach. Either would lead to feelings of anxiety. However a positive proactive approach would yield a positive outcome whereas a negative approach or an avoidance approach would leave the individual with not only the negative outcomes of stress but also feelings of inadequacy and low self-esteem. It has been seen that people who cope effectively with stressful situations have first learned to direct their thoughts along productive lines and avoid being distracted by fear and worry.

Positive Stress

Distress is generally an indication of a disharmony among different wants or needs within the person or between the person's inner wants and outside circumstances. Becoming aware of this disharmony is the first step towards resolving it either by avoiding it or by considering it as an opportunity for new learning, a change in direction or a positive approach to resolving the disharmony. Thus a moderate level of stress can have a positive impact. It could:

- help us to respond quickly and forcefully in emergencies
- be useful for performing well
- help us to realize our potential
- add zest and spice to life. Describing stress as spice Donald Tubesing says, "in the right proportion it enhances the flavour of a dish; too little produces a bland dish; too much may choke you."
- help us to come out of our comfort zone and stretch ourselves.

Self management

The way we cope with pressures depends on a personal trait known as sense of coherence (Autonosky, 1987) which is said to be the way we see the world as predictable and comprehensible. Sense of coherence involves three aspects:

- Comprehensibility;
- Manageability; and
- Meaningfulness

People high on comprehensibility believe their life and experiences in it are structured and predictable and not random and confusing. Manageability means that people believe they have adequate resources to meet the demands placed on them. Meaningfulness means people believe that life's problems and challenges are worth their investment of time and energy. Stress not only affects our bodies, but it also affects the way we think, feel and interact with others. Thus, stress management is more about self management and self control. Self control is the ability to control ourselves by being aware of and directing our actions to achieve specific goals (Karoly and Kanfer, 1982). It also implies self-direction. Once people view themselves as having choices and as being in control, they are most likely to deal effectively with stress (Fisher, 1984). We can have a greater sense of freedom if we think of self-control as an ability that we are capable of achieving, rather than as some inborn trait (Smith et.al, 1986).

Coping with stress

No single coping mechanism would really work for effectively dealing with stress. Some of the ways to effectively cope with stress are:

1. Changing your thought process: Overcome the self-imposed assumptions/restrictions with regard to self and also opportunities available.

About Self:

- Feelings of incompetence to deal with the demands
- Lack of confidence
- Tendency to focus on the negative aspects
- Fear of failure become greater than hope for success
- Feelings of discomfort with ambiguity and uncertainty
- Desire to continue in the comfort zone and unwillingness to exert/stretch oneself

About the Situation:

- Perceiving the situation as a threat rather than a challenge
- Considering it as a discontinuity

- Expecting the worse to happen

2. Managing self talk: Inculcate the habit of positive self-talk to boost your self-confidence and question your irrational beliefs and expectations.

3. Getting into some physical activity: Physical activity not only helps you in maintaining your physical health but it also refreshes you mentally and is considered to be a very useful stress reducing technique. Physical activities could be breathing exercises, muscle relaxation methods and other forms of physical exercises. Walking is considered to be the best and safest form for physical activity. Rippe and associates have brought out a variety of positive mental and physical benefits from walking in the Journal of American Medical Association (Rippe et. al. 1988). These include: staying lean, cleansing of your arteries, lowering BP, controlling blood sugar, conditioning your heart, stimulating bone marrow, improving physical functions (strengthening leg muscles, improving bowel function, strengthening bones).

Conclusion

It is a fact that stress is not similarly experienced by all people. The severity or gravity of a stressful situation depends on certain personality attributes like confidence, self-esteem, attitude, and certain qualities possessed by individuals like decision-making, sense of control, conflict resolution, possibility thinking. In that sense each individual has the capability to choose his/her response to a particular stimulus through his/her self-awareness, independent will, creative imagination and conscious decision. Only the capability varies from person to person.

Thus we need to understand that we have the ability to control and influence the environment and therefore are responsible for whatever is happening in their lives and career. Such an approach would limit the effect of other forces (external circumstances, condition or conditioning) in matters concerning oneself. If the meaning of life is the presence of difficulties, challenges, change and conflicts then we need to learn to confront, adapt and meet the challenges by enhancing our capability and thereby realizing our potential. This is possible by adopting an integrated holistic approach to stress management. Seen in this regard stress management can be considered to be a preventive mechanism to reduce the risk of illness and thereby aim at a sense of fulfillment in one's professional and personal life by adopting a balanced approach to life.

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The best portion of a good man's life is his little, nameless, unremembered acts of kindness and of love.

– William Wordsworth

Feature

Anthropometric Dimensions of Industrial Workers of Haryana State

Pankaj Chandna & Surinder Deswal

A survey was conducted to collect the anthropometric dimensions of industrial workers of Haryana State in the age group of 20 to 50 years. Twenty-eight anthro-pometric dimensions of 100 industrial workers were measured from different districts of Haryana State. Most of the measurements of the subjects were found to be higher than those of any other regions of India. The results presented in this work provide designers and engineers the basics for designing a safe, healthy and comfortable work environment and facilities for industrial workers of Haryana State.

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Anthropometric data provides information on static dimensions of the human body in standard postures. For years, anthropometry has been used in national surveys as an indicator of health status (Marks et al 1989). Anthropometric measurement of human limbs plays an important role in design of workplace, clothes, hand tools and many products. To design any product for human use, human factors engineers/ergonomists have to rely on anthropometric data, otherwise the output product may turn out to be non-ergonomically designed product or the product may turn out to be ergonomically incompatible (Haslegrave, 1986). Appropriate use of anthropometry in design may improve well being, health comfort and safety (Pheasant, 1998). New methods of anthropometric data collection that allow data to collect quickly and accurately, such as the use of computerized procedures, provides new opportunities for an anthropometric study (Paquette 1996, Roebuck 1995).

Studies of validity and reliability of anthropometric measurement methods have been performed (Feathers et al 2004, Meunier and Y in 2000.) Results of these studies suggest that the use of computerized methods for anthropometric data collection provides valid and reliable data.

Also for efficient design or design refinement of equipment, it is necessary to follow ergonomics guidelines and principles, which provides an orientation towards the physiological and psychological needs of an operator. The design of equipment is always a compromise between the operator's biological needs, which are determined by the ergonomics guidelines, and the physical requirements of the equipment (Das and Grady 1983, Das and Sengupta, 1996).

In this regard, the basic information required is the anthropometric body dimensions of the users of equipment i.e., industrial workers, which needs to be studied.

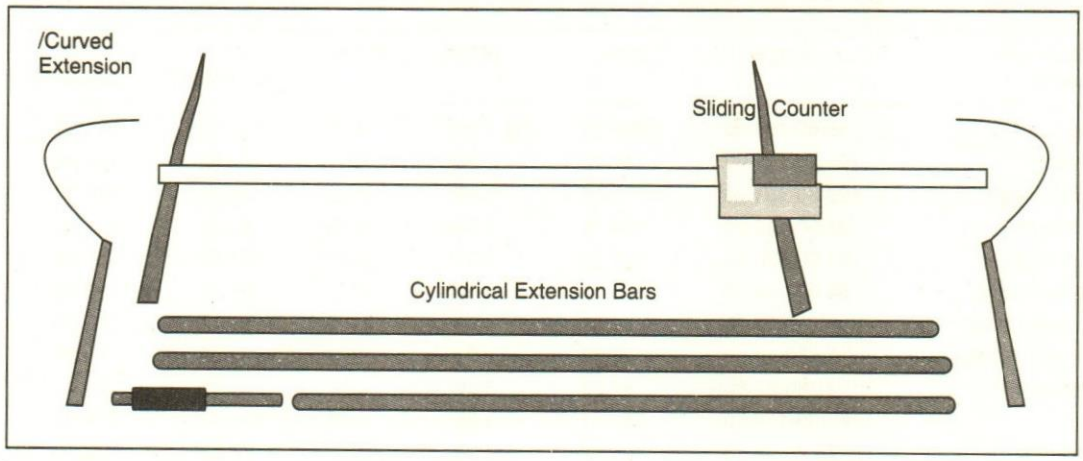

Fig. 1.

Gite and Singh (1997) informed that there is a considerable difference between the anthropometric data of Indians and westerners. Dewangan et al (2005) conducted a survey to collect the anthropometric dimensions of male farmers in the north-eastern region of India in the age group of 20 to 30 years, and found that most of the dimensions measured were lower than those from other regions except southern and eastern regions of India, and that all the dimensions were lower than those from other parts of the world. Moreover, anthropometry has been considered as the very basic core of ergonomics in an attempt to solve the real dilemma of fitting people to machines.

Literature review indicated that either no or very few studies have been conducted in the past to study the body measurement for industrial workers in Haryana state in particular. Haryana's rapid economic growth in recent years has led to a higher quality of life and subsequently concerted efforts to ensure a safe, healthy and comfortable work in an industrial setting. A large-scale anthropometric survey is one of the means of guaranteeing that such aspirations are being fulfilled. Keeping the above factors in mind the present study was undertaken to generate and analyse the anthropometric data of industrial workers of Haryana State.

Haryana lies in the northern region of the country surrounded by UP in the east, Punjab in the west, Rajasthan in the south and Himachal Pradesh in the north. Haryana covers an area of 44,212 sq kms and its population is 21,082,989 according to the 2001 census. It is an agricultural and industrial state. It is one of the major food producers of India. It houses major industries such as Maruti, Hero Honda, Honda, and Toyota etc. Risley (1915) classified the entire Indian population into seven racial types namely, Turko-Iranian, Indo-Aryan, Scytho-Dravidian, Aryo-Dravidian, Mongolo-Dravidian, Mongoloid and Dravidian. The people of Haryana belong to the Indo-Aryan type and in parts to the Indo-Dravidian type. They are divided into a number of castes (jatis) e.g. the Brahmins, the Rajputs, the Jats, the Ahirs and the allied agricultural communities. From the ancient past to the present, religion provides the main basis of the structure of the Haryana society.

Methodology

Subjects

One hundred people, 80 men and 20 women were measured from different districts of Haryana State. Mainly the industrial towns of Haryana like Faridabad, Ambala, Panipat, Gurgaon and Hisar were covered. Workers belonged to six small scale and medium scale industries in Haryana. Their age varied from between 20 and 50 years. We intend to develop a database which can accurately represent the population for which most design problems and solutions are aimed at.

Equipment Used

Standard anthropometric tools have been used since Richer first used calipers in 1890 (Anthropometry, 2000). In the present study Harpenden anthropometer (Figure 1) was used to take the measurements. The equipment is British made. It is a counter-recording instrument, which can be effortlessly operated from the tips of its branches. This instrument gives a direct and accurate reading, to the nearest millimeter, over a range of 50 mm to 570 mm. It is constructed mainly of light alloy anodized to its natural colour. Its sliding member operates via miniature ball-bearing rollers in order to ensure a movement which is free yet without cross-play.

Table 1: Anthropometric Dimensions of Industrial workers in Haryana State (all dimensions are in cms.)

Sr. No.	Anthropometric Dimensions	Range	Mean	SD	CV %	5th percentile	50th percentile	95th percentile
1.	Stature	155.50-184.00	167.72	7.40	4.41	155.90	167.00	180.36
2.	Eye height	145.40-172.20	156.35	7.10	4.54	145.80	155.20	168.36
3.	Acromial Height	128.50-151.20	138.04	6.89	4.98	128.58	136.90	150.64
4.	Elbow height	97.00-123.20	104.98	5.45	5.18	97.16	104.30	113.60
5.	Olecron height	101.00-126.40	107.30	5.31	4.95	101.00	107.20	116.52
6.	Iliocristale height	94.00-109.80	100.11	4.50	4.49	94.16	100.40	107.60
7.	Trochanteric height	80.40-95.20	88.65	4.60	5.19	80.72	88.20	94.48
8.	Metacarpal III height	63.80-76.50	70.32	3.33	4.73	63.88	71.00	75.58
9.	Knee height	41.80-52.00	47.55	2.99	6.28	41.96	48.40	51.62
10.	Span	169.60-176.20	173.65	1.55	0.89	170.00	174.00	176.00
11.	Span akimbo	78.20-92.50	85.77	4.16	4.84	78.36	86.00	91.28
12.	Waist back length	37.90-46.50	41.88	2.07	4.94	37.98	41.60	44.70
13.	Bideltoid breadth	32.80-45.30	39.63	2.89	7.30	33.12	40.30	43.04
14.	Waist breadth	19.80-28.90	24.55	2.17	8.82	20.12	24.20	27.70
15.	Chest breadth	19.70-29.00	26.03	2.39	9.16	20.10	26.50	28.72
16.	Interscye breadth	21.80-31.00	27.35	2.45	8.95	22.12	27.60	30.82
17.	Hip breadth	23.90-32.40	29.56	2.21	7.48	24.30	30.30	31.60
18.	Chest circumference	78.00-98.00	82.05	4.52	5.51	78.00	80.00	91.20
19.	Wrist circumference	12.00-16.00	13.88	1.18	8.56	12.00	14.00	16.00
20.	Waist circumference	71.12-88.90	78.16	4.24	5.42	71.12	78.74	86.87
21.	Thigh circumference	40.00-52.00	43.72	3.22	7.36	40.00	43.00	51.20
22.	Calf circumference	24.00-34.00	29.61	2.45	8.28	24.80	30.00	34.00
23.	Sitting Height	76.60-94.00	84.26	5.09	6.04	76.92	83.60	93.60
24.	Sitting Eye Height	65.50-83.20	73.77	5.13	6.95	65.90	73.40	82.78
25.	Sitting acromial height	50.00-64.20	56.64	3.70	6.52	50.80	57.60	63.08
26.	Popliteal Height	35.60-45.80	41.87	3.02	7.21	35.92	42.60	45.32
27.	Buttock popliteal height	32.80-47.60	40.94	4.73	11.56	33.12	39.70	47.24
28.	Forearm hand length	42.00-47.60	45.65	1.32	2.89	42.08	46.00	47.08

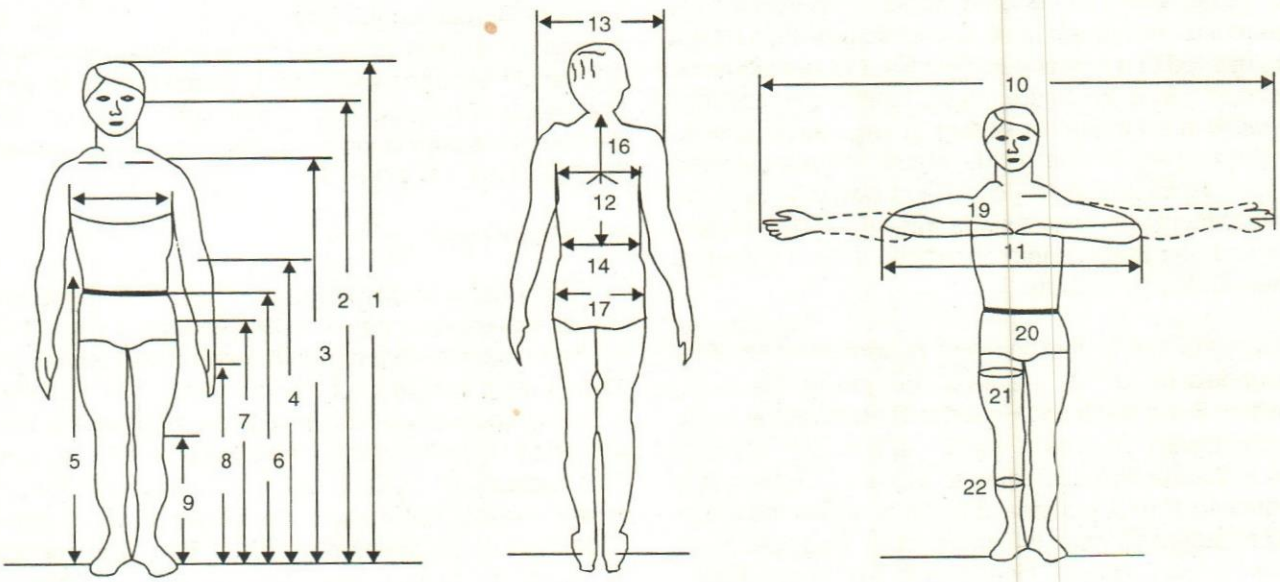

Fig. 2. Anthropometric dimensions in standing posture

The equipment consists of the following parts:

A sliding numeric counter which moves on the teeth of the bar it is attached to.

Four cylindrical extension rods, two of them 500 mm, one rod of 400 mm and the fourth one of 100 mm.

Two extension rods curved at the end for measuring circular dimension.

Range of Dimensions Measured

A study was carried out in order to determine the accuracy insured by the Harpenden anthropometer. The study was carried out in the college hostel using the hostel residents as subjects. All the 28 dimensions were measured to get acquainted with the anthropometer and human body dimensions. Also six human body dimensions were measured using the traditional calipers and measuring tape. The data so obtained was compared with the data given by Harpenden anthropometer. The result showed that the data taken using the traditional equipments had an error of 4-7 mm.

A total of 28 static anthropometric dimensions were recorded for each individual. Twenty-two dimensions were measured while the individual remained standing, while the remaining was taken while the individuals remained seated. The particulars of these anthropometric dimensions were taken from the recommendations of the conference on standardization of Anthropometric Technique and Terminology (Hertzberg, 1968). The landmarks of the dimensions measured in standing and sitting postures are shown in Figure 2 and Figure 3 (Gite and Chatterjee 1999). Data was collected during working hours only. Primary data collected in the study were used to compute range, mean, standard deviation (SD), coefficient of variation (CV), 5th, 50th and 95th percentile value for each anthropometric dimension using the Microsoft Excel (USA) 2003 software package.

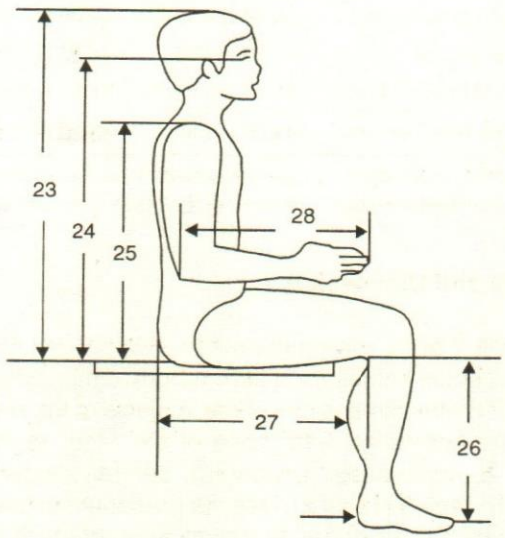

Fig. 3. Anthropometric dimensions in sitting posture

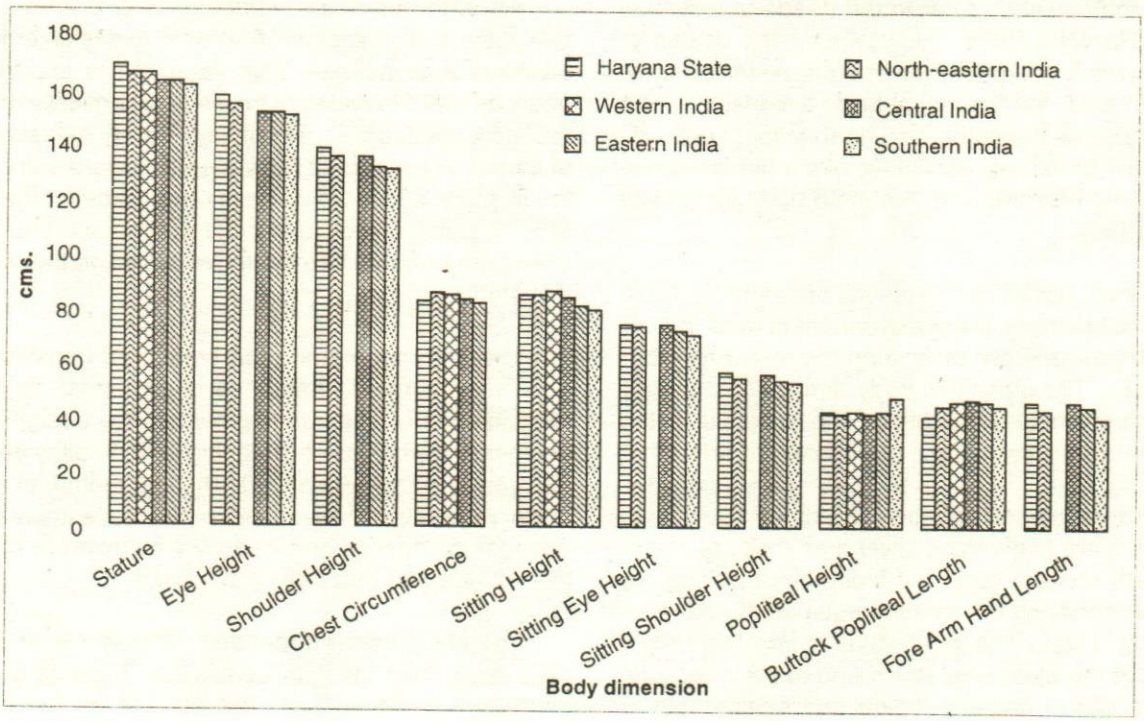

Fig. 4. Comparison of mean of body dimensions of subjects of Haryana State with those of other regions of India.

Table 2: Comparison of mean (standard deviation) of anthropometric data of Haryana State with those of other regions of India (all dimensions are in cms)

BodyDimension	Haryana State (n=100)	North-eastern[a] India (n=280)	Western India (n=40)[b]	Central India (n=39)[c]	Eastern India (n=134)[d]	Southern India (n=128)[e]
Stature	167.72 (±7.40)	164.87 (±4.54)	162.10 (±5.80)	162.00 (±4.95)	160.70 (±6.00)	164.60
Eye Height	156.35 (±7.10)	153.55 (±5.00)	150.80 (±5.10)	151.00 (±5.22)	149.70 (±6.10)	-
Shoulder Height	138.04 (±6.89)	134.47 (±4.30)	131.20 (±4.80)	134.60 (±4.87)	130.10 (±4.60)	-
Chest Circumference	82.05 (±4.52)	84.74 (±3.68)	81.30 (±4.87)	83.10 (±4.48)	-	84.30
Sitting Height	84.26 (±5.09)	84.70 (±2.88)	80.90 (±2.20)	83.80 (±2.52)	79.10 (±4.00)	86.20
Sitting Eye Height	73.77 (±5.13)	73.38 (±3.17)	71.40 (±2.00)	73.90 (±2.62)	70.10 (±4.60)	-
Sitting acromial Height	56.64 (±3.70)	54.30 (±2.74)	53.40 (±2.12)	55.70 (±2.08)	52.90 (±3.90)	-
Popliteal Height	41.89 (±3.02)	41.25 (±2.56)	42.00 (±1.74)	41.60 (±2.07)	47.10 (±3.50)	42.00
Buttock Popliteal Length	40.94 (±4.73)	44.52 (±2.45)	46.20 (±1.96)	46.60 (±1.75)	44.70 (±2.30)	45.60
Fore Arm Hand Length	45.65 (±1.32)	43.20 (±0.56)	44.60 (±1.96)	45.90 (±2.00)	40.10 (±1.40)	-

n = number of subjects [a]Dewangan et al (2005) [b]Sen (1964)
[c]Gite and Yadav (1989) [d]Yadav et al (1997) [e]Fernandez and Uppugonduri (1992)

Results and Discussion

Table 1 gives the range, mean, SD, CV, 5th, 50th and 95th percentile values for different body dimensions. The anthropometric dimensions of the subjects of the Haryana state are compared with those of the other regions of India, i.e. north-eastern, western, central, eastern and southern region (Table 2). Results presented in the Table 1 facilitate the designer to select appropriate body dimension for the design of new equipment or refinement of existing equipment to cater to the needs of industrial workers in Haryana State. However for the design of equipment, which is expected to operate under dynamic conditions in field, the functional body dimension of the operator has to be considered. The functional body dimension is the better representative of the human activities and it is determined from the state body dimension (Kroemer, 1983).

It is obvious, based on the results presented in Table 2, that the subjects of the Haryana State who mainly belong to Aryan race are taller than those of any other region of India. The other two body dimensions namely eye height and shoulder height of the subjects of the Haryana State are also larger than those of any other region of India. Mean values of two other dimensions i.e. chest circumference and sitting height of the subjects of Haryana State are found to be lower than those of southern and north eastern region of India, emphasizing the necessity of modifying the existing equipment before introducing in this state. The mean value of Popliteal Height of Subjects of the state was also found to be lower than the subjects of the eastern region and comparable to other regions of India. Also the mean value of Buttock Popliteal Length of Subjects of the state was also found quite lower than any other regions of India, indicating a unique and distinct nature of the anthropometry of the state. Comparisons of mean values of different dimensions of the subjects for Haryana State with those of other regions of India are also shown in figure 4.

Conclusion

An anthropometric database is a prerequisite for designers and engineers if they want to design ergonomic products and facilities. This database is important for users as well if they desire to use ergonomically designed products and facilities. Twenty-eight body measurements of Industrial workers of Haryana State were summarized in this project. This would be of great value for the design of work stations, tools and protective equipment. The following conclusions can be drawn based on the results of this study:

The anthropometric data presented constitutes the first anthropometric database of industrial workers of Haryana State. This work provides the designers and engineers the basics of designing safe, healthy and comfort work environment and facilities for industrial workers of Haryana State. This data can further be analyzed and used for production and inventory planning to meet the market demand and reduce the costs.

The equipment, Harpenden anthropometer, is standard equipment for data acquisition. Most of the measurements of the subjects are higher than those of any

other regions of India; therefore, there is a need for refining the design of existing equipment based on ergonomic considerations before introducing them to Haryana State.

Quality of life can be improved by applying anthropometric data, which can be regarded as an indicator of life quality for the state. This study has laid the groundwork for improving the worker's safety, health and life quality in Haryana State.

Further work and effort can be made to transfer the data into practical dimensions that designers and engineers may use conveniently for various products and facilities. Also, there is a need to enlargen the sample size as the data of 100 individuals is small to construct a relevant database which can be used for broader prospects.

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□

A professional is someone who can do his best work when he doen't feel like it.

– Alistair Cooke

Feature

The Relationship between Organization Structure and Perceived Innovation in the Transmission and Distribution Sector of India

Meenakshi Gupta & Yamini Prakash

There is a need to re-examine the factors that help innovations in the traditional manufacturing sector, to indicate whether or not with the passage of time structures of manufacturing organizations have undergone a change in order to spur innovation. This study focuses on structure-innovation relationship in the manufacturing (Transmission & Distribution) sector.

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Innovation, the need of the hour, can accelerate the Indian market and business activity considerably. India needs to bring in continuous innovation to keep pace with global economy. Broadly "innovation not only includes development of new products and services, but also new operating practices (processes), managerial tactics and even business strategies. It may not always be a process of creating, rather a process of building, improving and adapting" (Youtie, 2003). It is important for organizations to innovate at all levels today, whether they in technology, products or processes (Gautam and Chaudhary: 2004).

Structural factors which facilitate innovations may vary with the nature of activity involved, differing from the manufacturing to the service sector. A large number of current research on innovation focus on studying the more recent and upcoming service sector. Some researchers indicate that the organization structure in the services industry is rapidly undergoing a change to facilitate the process of innovation.

Literature Review

According to Woodward (1980) in unit production (which is characteristic of 'one-off' or 'tailor-made' production in transmission and distribution firms), short and broadly-based pyramids predominated and ensured success. She found that there was a tendency for organic management systems and flexibility to predominate and bring success in unit production.

Formalization and Innovation

Srivastava (1991) posits that formalization through

various rules and procedures creates a feeling of security in the organization, protecting employees from arbitrary management decisions. Taking a positive view of formalization, he says that formalization leads to commitment, involvement and increases organizational effectiveness; as it reduces role conflict and enhances role clarity. Besides, formalization leads to administrative efficiency and to that extent it helps innovations. Bartol and Martin (1991) posit that rules and procedures help provide coordination and better direction. March and Heath (1994) say, "Rules store knowledge and such knowledge enables organizational members to solve problems in a highly flexible fashion". On the basis of literature survey, Service and Boockholdt (1998) conclude that a strong control system helps organizational innovations. Wijnberg, Ende and Wit (2002) report that formalization increases the accountability of decision makers towards each other and towards the organization as a whole. Khandwalla (1995) found significant correlations between high formalization and implementation of innovations in bureaucratic organizations of India. A greater autonomy-flexibility approach at implementation stage might even be harmful for innovations according to Drach-Zahany, Somech, Granot and Spitzer (2004).

Centralization and Innovation

Bartol and Martin (1991) state that decentralization facilitates innovations. Rothwell (1992) posits that greater empowerment and increased decision making at a lower level of management reduces the number of approvals required for a decision. Further empowered project managers add to the speed and efficiency of new product development. Pavitt (1994) found that effective commercial exploitation of technology for innovation required decentralization for rapid decision making. Khandwalla (1995) posits that decentralization has positive motivational effect over employees. West (2000) provides support that high centralization is a negative predictor of innovations. In his study Vedamanickam (2001) found that decentralization was positively correlated with workplace innovativeness. Shavinina (2003) suggests that empowered multi-functional teams are more successful at innovating. Further Kanter (2004) says innovative organizations are more decentralized. McNulty and Ferlie (2004) posit that innovations increasingly require decentralization today. The findings of Khandwalla and Mehta (2004) indicate that extensive decentralization helped innovations. To sum up decentralization improves democratic decision-making, fosters responsiveness among employees, and enhances the ability of lower levels to influence management (Samaratunge, 2003), which facilitates innovations.

Concentration of Authority and Innovation

Research which has shown a relationship between concentration of authority and innovation are common to those showing relationship between Centralization and Innovation.

Participation in Decision Making and Innovation

West (1990) defines "*Participative Safety*" as a sense that team members can participate in decision-making and can share ideas without fear, and considers it important for innovation. Further, participation has been found to increase organizational commitment and promote better interpersonal relationships among employees (Srivastava, 1991). Lowe (1995) posits that participative structures are most appropriate for innovations. Khandwalla (1995) found positive correlations between participation in decision-making and organizational innovations in an Indian sample. Dunphy and Bryant (1996) found that in self-managed teams, team members interact with each other rather than relying on higher authority for decisions. This increases the speed of innovation by speeding the decision-making process. Strauss, Heller, Pusic and Wilpert (1998) say that participation fosters integration. Where there are high levels of participation in decision-making, there is more information exchange and interaction within groups. These groups are more likely to work through difficulties associated with introduction of innovations. They process information and opinions about the innovation more comprehensively, ensuring more effective outcomes. This not only increases the chances of success of particular innovations, but also increases receptivity to future innovation. For Shadur, Kienzle and Rodwell (1999), high participation in decision-making leads to greater commitment and organizational involvement.

Mintrom (2003) suggests that more inclusive and participative decision-making process in organizations can promote innovations. Hamel and Getzel (2004) emphasize employee participation for innovations. Khandwalla and Mehta (2004) found that decisions in innovative organic structures emerged through participation of those involved in and affected by the decision directly.

Research Hypothesis

Hypothesis 1 Hierarchy is significantly related to Perceived Innovation.

Hypothesis 2 Formalization is positively related to Perceived Innovation.

Hypothesis 3 Centralization is negatively related to Perceived Innovation.

Hypothesis 4 Concentration of Authority is negatively related to Perceived Innovation.

Hypothesis 5 Participation in Decision Making is positively related to Perceived Innovation.

Research Methodology

Operationalizing Research Variables

The independent variable in the study is Organization Structure, comprising three components (hierarchy, formalization and centralization). Centralization is further composed of two sub-components: concentration of authority and participation in decision-making, both of which have also been analyzed as independent components of structure. The dependent variable is perceived innovation. Operational definitions of research variables follow:

Organization Structure

It refers to the way in which work and workers are organized in an enterprise; with the help of formal rules and procedures; by dividing them according to their functional expertise; and by prescribing methods of functioning and roles that organizational members need to perform; and by investing the power to take decisions at desired organizational levels in the desired personnel.

Components of Organization Structure

Hierarchy

It refers to the degree to which an organization is divided vertically into various organizational levels, varying in the degree of authority enjoyed by each level.

The variable is measured in the study by counting the total number of vertical levels and sub-levels in an organization between the top management and the lowest worker. Data for hierarchy has been collected from organizational records (secondary data). Number of vertical levels were 6 for one of the organizations surveyed, while for the other it was 11.

Formalization

Formalization is defined in the study as the extent to which employee behaviour and job/role specifications are regulated and standardized by the use of formal rules, procedures, and task definitions.

Formalization has been measured by Hage and Aiken's (1977) "Formalization Inventory".

Centralization

This refers to the degree to which authority for decision making in an organization is concentrated at a single point or organizational level.

In the present study centralization is conceptualized as comprising two sub-components, which have also been analyzed as separate components of structure. Hence, centralization is measured by combining two scales, one for each of the two components, administered as a single scale. The two components are:

(a) Concentration of Authority: It is the extent to which the decision making power is concentrated at higher managerial levels.

Concentration of authority is measured by "Delegation of Authority" scale, devised by Daftaur (1988).

(b) Participation in Decision Making: It refers to the degree of participation in the decision-making process, of members from different hierarchical levels and functional units in an organization.

Participation in decision making is measured by Hage and Aiken's (1977) "Scale of Personal Participation in Decision-Making".

Perceived Innovation

It portrays employee perception of how innovative they consider their organization in the present and in the past, at the three levels of production: input, throughput and output. The measure also includes employee perception of the organization's overall approach to innovation and innovative activity.

Perceived innovation is measured using a scale of perceived innovation, designed by the researcher.

Description of Test Instruments

The psychological test instruments used to measure variables under study include four rating scales and a semi-structured interview.

Psychological Rating Scales

The questionnaire for research survey consisted of four rating scales. The first scale measures formalization. Two scales were combined to form the second,

scale for centralization; and the third one was designed by researcher, to measure 'perceived innovation'. The entire sample (N = 120) was subject to questionnaire survey.

Formalization Inventory

Formalization was measured by Hage and Aiken's Formalization inventory, cited in Miller (1977, pp. 284, 285, 286) Formalization Inventory. This scale consisted of 15 items, each to be rated on a 4-point rating scale, where each point stands for: 1-definitely true, 2-true, 3-false and 4-definitely false. On each item, 4 was the highest score and 1 was the lowest score. Item nos. 6, 7, 9, 10, 11, 12, 13, 14, & 15 were reversed. These items were not negatively worded, but a high score on them indicated low score on formalization.

The criterion validity of the scale has been given, the criterion measure used was 'alienation'. Formalization is positively related to 'alienation'. The greater the degree of formalization in the organization, the greater the likelihood of alienation from work. Dissatisfaction with work is high in organizations where jobs are rigidly structured. Strict enforcement of rules was strongly related to work dissatisfaction. Social relations are also disturbed when rules are strictly enforced. Significant positive relationships were found between routine work and rule manual, job description and specificity of job descriptions.

Centralization Scales

Since centralization is conceptualized as comprising two sub-components; hence, the scale measuring centralization was formed by combining two scales: one for 'concentration of authority' and the other for 'participation in decision-making'. The entire instrument administered to the subjects consists of 8 items, 4 items from each of the two scales, both rated on a 5-point rating scale. The values on the scale varied in intensity from 'never' at point 1 to 'always' at point 5.

(a) Scale of Personal Participation in Decision Making: Hage and Aiken's scale cited in Miller (1977, pp. 287, 288, 289) was used to measure Participation in Decision-Making. It was a Likert-type 5-point rating scale, where each point stands for: 1-never, 2-seldom, 3-sometimes, 4–often, 5-always. A score of 1 indicated lowest score and a score of 5 indicated highest score on each item. During scoring, none of the items were reversed.

The Criterion Validity measure used here was that of 'Autonomy'. Organizations, in which decisions were made by only a few people at the top, relied on rules and close supervision as a means of ensuring consistent performance by the workers. These organizations were also characterized by a less professional staff. The presence of a well trained staff is related to a reduced need for extensive rules. Organizations that are highly autonomous tend to have a non-participative internal decision structure. The greater the autonomy, the larger is the executive's span of control.

(b) Delegation of Authority Scale: Authored by Daftaur, cited in Pestonjee (1988, pp. 233, 234), this scale measures Concentration of Authority. It is a Likert-type, 5-point rating scale, where each point stands for: 1-never, 2-seldom, 3-sometimes, 4–often, 5-always. A score of 1 indicated highest score and a score 5 indicated lowest score on each item. The lower the concentration of authority score of an individual, the higher the centralization score, and vice versa. Only 1 item was reversed although it was not negatively worded. Cronbach's alpha coefficient of reliability =.95

The delegation of authority scale was used in combination with the participation in decision making scale in order to arrive at a combined score of centralization.

Scale for Perceived Innovation (see Appendix I)

Perceived innovation was measured with the help of a scale designed by the researcher. It assessed how innovative employees perceive their organization to be, and also judged employee attitudes regarding organizational approach towards innovative activity. It consisted of 20 items, to be rated on Likert-type, 5–point rating scale, varying in intensity from 'strongly disagree' as point 1 to 'strongly agree' as point 5, with undecided as the midpoint, 3. On each item, a score of 5 indicated highest score on perceived innovation, while 1 indicated lowest score. Employees were requested to avoid the midpoint 3, as much as possible.

Test-retest reliability was .86. Internal consistency validity, calculated by the inter-item consistency method was .90.

The Interview Schedule (see appendix II)

The research survey was done using both quantitative and qualitative techniques. The data produced by interviews was analyzed qualitatively using content-analysis. Questions in the interview schedule were open-ended and covered all different relationships studied by this research.

Description of sample

A stratified sample of 120 employees from two organizations of India manufacturing 'tailor-made' transformers were selected for data collection. 80 subjects were from a reputed organization of Allahabad, out of which 65 were subject to detailed interviews. 40 subjects were from a leading organization in Mumbai, out of which 28 were interviewed. In all, 93 employees were subject to detailed interviews. The sample consisted of employees from across design, production, engineering & technology, marketing, quality control and purchase departments.

Results

Quantitative Analysis

Table 1: Correlating Structural Variables with Perceived Innovation

N = 120

Variables	Pearson's Correlation	Level of Significance
Formalization	r = .46	p < .01
Centralization	r = –.04	–
Concentration of Authority	r = .20	p < .05
Participation in Decision-Making	r = .17	p = .05

Table 1 shows a positive and significant relationship between formalization and perceived innovation, a negative but not significant relationship between centralization and perceived innovation, a positive and significant relationship between concentration of authority and perceived innovation, and a positive and significant relationship between participation in decision-making and perceived innovation.

Table 2: One-Way ANOVA with Perceived Innovation

N = 120; df = 1, 118 ** p = .01, *p = .05

Variables	Levels	N	Means	S.D.	F-Ratio
Hierarchy	Low	80	78.03	9.44	F = 15.24**
	High	40	70.70	10.17	
Formalization	Low	67	71.96	10.72	F = 22.41**
	High	53	80.17	7.51	
Centralization	Low	80	75.55	10.53	F = .003
	High	40	75.65	9.78	
Concentration of Authority	Low	99	74.70	10.30	F = 4.35*
	High	21	79.76	9.13	
Participation in Decision-Making	Low	59	74.49	10.55	F = 1.32
	High	61	76.64	9.91	

The table for one-way ANOVA shows a highly significant relationship between hierarchy and perceived innovation. Findings also indicate a significant difference in the perceived innovation scores of employees belonging to organizations with low level of hierarchy, and those belonging to organizations with high level of hierarchy. The table shows highly significant relationship between formalization and perceived innovation, and a significant relationship between concentration of authority and perceived innovation. However, it does not show significant relationship between centralization and perceived innovation, and between participation in decision-making and perceived innovation.

Qualitative Analysis

The following results were obtained from a content-analysis of the data collected by interviews. A majority of employees say that a low level of hierarchy facilitates innovation (50.54%). Quantitative analysis also shows a significant relationship between the two variables. A majority, 61.29% employees, say that formalization 'often' leads to innovations, and 20.43% say that formalization 'always' leads to innovations. Hence, a total of 81.72% of employees, support a positive relationship between formalization and innovation. Both correlations and ANOVA show a significant relationship between the two variables, the former showing a positive relationship. A majority of employees support a negative relationship between centralization and innovation (77.42%). Correlations show negative but not significant relationship between the two variables. 26% employees say that low level of concentration of authority 'always' leads to high number of innovations. 21% employees say 'often' this relationship persists. Thus, a total of 47% employees supported a negative relationship between concentration of authority and innovation. 53% employees did not support the negative relationship; out of these 46% said 'sometimes' low concentration of authority leads to high number of innovations and 7% were undecided. Hence, nature of this relationship has not been clearly indicated by qualitative data. Both ANOVA and correlations show significant relationship between concentration of authority and innovation, the latter showing positive relationship. A further 52% employees say that high participation in decision-making 'always' leads to a high number of innovations. 30% say high participation in decision-making 'mostly' leads to high number of innovations. Hence, a total of 82% were in favour of a positive relationship between participation in decision-making and innovation. Correlations also show positive relationship between the two variables.

Discussion

Results of correlation show a highly significant and positive relationship between formalization and perceived innovation. Positive and significant relationship between concentration of authority and perceived innovation, and positive and significant relationship between participation in decision-making and perceived innovation was obtained. The relationship between centralization and innovation was not significant, but shows a desired negative value.

Hence, results indicate that in the transmission and distribution sector, the greater the formalization the greater is the level of perceived innovation, greater the concentration of authority the greater the perceived innovation, and greater the participation in decision-making the greater is the level of perceived innovation. It indicates that formalization, concentration of authority and participation in decision-making are facilitating innovation. A low level of centralization (decentralization) may be helping innovations, but not significantly.

Hierarchy and Perceived Innovation

Results of one–way ANOVA (table 2) show a highly significant relationship between hierarchy and perceived innovation. The qualitative analysis supports statistical findings. A majority, 50.54% of employees, say that a low level of hierarchy facilitates innovations. Hence, hypothesis 1 has been supported.

Formalization and Perceived Innovation

Formalization shows positive relationship with perceived innovation, as has been observed from correlation findings, supported by ANOVA. The finding has been supported by qualitative analysis also. A majority of employees support a positive relationship between formalization and innovation (81.72%). Hence, hypothesis 2 has been supported.

The understanding of the relationship between formalization and innovation has been simplified by the definition of innovation by Prasad et. al. (1995), which says, 'innovation means implementing change in authority that is established.' Srivastava (1991) found that formalization led to administrative efficiency, and to that extent it helped innovations. He says that through various rules and procedures formalization creates a sense of security in the organization; protecting employees from arbitrary management decisions. Hence, formalization leads to employee commitment and involvement, reduces role conflict and enhances role clarity by establishing organizational standards.

Bartol and Martin (1991) find that rules and procedures help provide coordination and better direction to activities by setting task priorities and task deadlines. These play an important role in successful innovation. March and Heath (1994) find a positive relationship between formalization and innovations. They posit that *Rules Store Knowledge*, and such knowledge enables organizational members to solve problems in a flexible fashion.

Khandwalla (1995) found positive correlations between formalization and innovation implementation in a few organizations of India. On the basis of literature survey, Service and Bockholdt (1998) conclude that formalization helps innovation. Wijnberg et. al., (2002) found that formalization increases accountability of decision makers towards each other, and towards the organization as a whole, bringing about order and enabling innovations. Drach-Zahany et. al. (2004) found that formalization settles ambiguity and uncertainty, provides guidelines for practice, and enhances performance. They found that more autonomy and flexibility at the implementation stage might even be harmful for innovations.

An argument that employees interviewed had to offer in favour of a positive relationship between formalization and innovation, was that rules and procedures bring about discipline and responsibility among employees. Since in the organizations surveyed, a sizeable number of employees were constantly working in project/product teams, they had to be coordinated by rules. The more important requirement, however, was for meeting deadlines. Teamwork required employees from various departments to work together in multidisciplinary groups. These teams had to meet deadlines in order to preserve customers. According to the employees interviewed, formalization was thus important for innovation.

Jassawalla and Sashittal (2003) say that it should be made obligatory for employees to follow rules, because if the processes and systems for new product development were left to the employees, they would create self-serving organizations. Too little of formalization would make it difficult to coordinate change.

To conclude, contrary to a number of researchers but in agreement with several others; employees view formalization as a tool for discipline rather than for control, in the sample surveyed.

Centralization and Perceived Innovation

Correlation does not show a significant relationship between centralization and perceived innovation. How-

ever, it shows a desired negative direction to the relationship. The qualitative analysis indicates a negative relationship between the two variables. A high, 77.42% employees, say that low level of centralization leads to a high number of innovation. Hence, hypothesis 3 has received partial support from data. Both quantitative and qualitative results show negative relationship. The difference between significance levels of the two findings may be due to difference in employees comprising interview sample from the total sample.

Bartol and Martin (1991) found that low centralization was favourable for innovations. Pavitt (1994) found that decentralization was important for innovative organizations, for rapid decision-making and effective commercial exploitation of technology. Rothwell (1992) says decentralization plays an important role in rapid and successful new product development. Increased empowerment at lower levels of management reduces number of approvals required for a decision. This finding has been supported by employee interviews. Employees say, since lower level employees are directly concerned with the manufacturing plant, machinery and labour; they are most aware of day-to-day problems. Their empowerment would speed up decision-making and save time.

Khandwalla (1995) found that decentralization had positive motivational effect, hence contributed to innovations. West (2000) shows high centralization as a negative predictor of innovations. Vedamanickam (2001) found a negative correlation between centralization and workplace innovativeness. Shavinina (2003) found that innovative organizations had low level of centralization. McNulty and Ferlie (2004) and Khandwalla and Mehta (2004) also found evidence in favour of extensive decentralization for innovations. Kanter (2004) concludes that innovative organizations were more decentralized. To sum up, decentralization facilitates innovation by improving democratic decision-making, fostering responsiveness among employees, and enhancing the ability of lower levels to influence management through empowerment and shared decision-making (Samaratunge, 2003).

Evidence from interviews with senior management indicate that decentralization allows an organization to rapidly respond to changing environmental conditions resulting from market competition, since decision-making is faster. It could be regarded as a stimulating factor for employees to take control of their tasks. With decentralization comes greater job satisfaction, greater flexibility in one's performance of duties, greater opportunities of doing new things and in different ways, hence for creativity and innovation. This field evidence supports existing research literature.

According to interviews across other management levels, low level of centralization facilitated innovation, as there was greater autonomy and flexibility in taking decisions regarding one's work. Employees were free to prioritize and time their work, and for every work they need not consult their superiors. Hence, there was greater motivation to work, which led to organizational commitment. Employees expressed that with decentralization, decision-making was faster with less wastage of time. This speeded up the implementation process. They said decentralization was positive for both initiation and implementation of innovations.

When working in project teams, decentralization was important for better coordination of employees. As per observations of the researcher in the organizations surveyed, through decentralization power was released to teams and then dispersed between members of the team. These organizations were in the practice of *selective vertical and horizontal decentralization.* Such a process was very positive for innovations.

Concentration of Authority and Perceived Innovation

A positive relationship between concentration of authority and perceived innovation was shown by significant correlation and ANOVA values. Qualitative results of this relationship do not clearly show a negative or positive relationship between the two variables. Hence, hypothesis 4 was not supported by either quantitative or qualitative analysis.

Participation in Decision-Making and Perceived Innovation

Correlation findings show a positive relationship between participation in decision-making and perceived innovation. Qualitative analysis shows that a majority of employees support a positive relationship between participation in decision-making and innovation (82%). Hence, hypothesis 5 has been supported.

West (1990) identifies *Participative Safety* as important for innovation, and participative safety comes with participation in decision-making in an organization. Bartol and Martin (1991) found that involving employees across the organization in development of ideas often positively influences their willingness to help implement these ideas. Participation facilitates employee performance by increasing organizational commitment, and promoting better interpersonal relationships according to Srivastava (1991). This view has also been expressed in employee interviews. Employees said participation improves communication throughout the organization by opening communication channels both horizontally and

vertically. Hence, employees are aware of activities going on in other departments, and can relate activities of their department to the rest of organization.

Khandwalla (1995) found positive correlations between participation in decision-making and organizational innovations in an Indian sample. Lowe (1995) also reported similar findings. Dunphy and Bryant (1996) found that with high participation in decision-making, decision-making process is speeded up; as reliance upon higher levels decreases, and this helps innovations. Strauss et. al. (1998) found that where there were high levels of participation in decision-making, there was greater information sharing and interaction within groups. It is more likely that these groups will work through difficulties associated with introduction of innovations. Information and opinions about innovation and innovation process are worked out more comprehensively. Thus participative decision-making for innovations is more effective in comprehensively solving an informational conflict. This not only increases the chances of success of a particular innovation, but also increases receptivity for future innovations.

Mintrom (2003) found that a more inclusive and participative decision-making process in organizations can promote innovation. For this an organization's bottom line must be closely tied in the deliberative decision-making. Khandwalla and Mehta (2004) found that participation in decision-making helped those employees in problem-solving who were affected by the decision directly. This finding has been supported by employee interviews. Besides, Hamel and Getzel (2004) also emphasized employee participation for innovation.

Employees from various organizational levels said in their interviews that participation especially of lower levels in the decision-making process helps innovation. Since they are actually involved in the manufacturing process, therefore, their ideas are fruitful to the organization. When ideas come from various parts of the organization and are discussed in groups representing different specialized areas and hierarchical levels, it is an enriching exercise for innovations. Not only does an idea become rich technically in content, but its marketability and other implications are also discussed in such participative sessions. There is less wastage of time and decision-making and implementation is speeded up. Participation thus is helpful for both idea-generation and implementation according to employees interviewed.

As expressed by senior management, participation helps the organization to come up to, or even lead the competitive standards of the environment by helping innovations. Employees from other management levels say participation leads to greater organizational commitment, job involvement and job satisfaction among employees. Shadur et. al., (1999) had found that participation in decision-making led to job-involvement in employees. Such factors help to spur innovations.

To sum up the findings: Statistical analysis shows a positive relationship of formalization, concentration of authority, and participation in decision-making; with perceived innovation. It also shows a significant relationship between hierarchy and perceived innovation. Content analysis shows positive relationship of formalization and participation in decision-making; with perceived innovation. It also shows a negative relationship of hierarchy and centralization, with perceived innovation.

Conclusion

Contributions

This single study explores the effect of five structure variables on organizational innovation, hence is enriching. The five variables are components of structure: Hierarchy, Formalization, Centralization, Participation in Decision Making, and Concentration of Authority.

Perceived innovation is measured by a scale designed and validated by the researcher. The scale measures employee perceptions about organizational innovations at the three levels of production (input, throughput, output), and of the organization's approach towards innovation/innovative activity. The scale has been validated by inter-item consistency, and reliability has been obtained by the test-retest method. Both the reliability and validity were high. This scale is one of its kind, since it is difficult to find a documented counterpart in the research literature available.

This study hypothesizes a positive relationship between formalization and innovation. It examines the effect of formalization on innovation and proposes, contrary to some researches but in agreement with several others, that formalization is positively related to innovation. The study equates formalization to the concept of discipline, rather than the more popular conceptualization as control. However, further research needs to elaborate on the relationship.

Limitations of the Study

The first limitation maybe with the scale for perceived innovation. This is because a factor analysis of the scale has not been conducted, and so complete psychometric properties have yet to be determined. It has only been

validated for use in the present study. The scale could have accounted for some of the limitations in the data.

Another limitation could have been created by the difference in employees comprising the interview sample (93) from total sample (120) which was administered questionnaires. It may be due to this that the nature of some findings vary across qualitative and quantitative analysis.

A third limitation may be the difference in the total number of employees who participated in the study from the two organizations surveyed. Out of the total 120 employees, 80 were from one organization, while 40 belonged to another. Hence, it is likely that greater impact on findings could have been created by the organization contributing greater number of employees.

Yet another minor limitation of the findings could have been due to the difference in geographical location of firms. Difference in the level of employee exposure are obvious, along with socio-cultural differences between the two cities. This difference was especially observed at junior management and supervisory-staff levels, and could have influenced perception and attitudes of employees. However, this difference did not appear to be a major one.

Suggestions for future Research

There is need for more elaborate and detailed research to explore the relationship between structural variables and innovation.

Measurement of innovations is a complicated and difficult task. The perceived innovation scale designed for the purpose of this particular study, maybe further standardized with complete psychometric properties.

Suggestions and Applications for Industry

There is a need to increase the level of participation in decision-making to facilitate innovations in the organizations surveyed. It was observed that both organizations required greater involvement of employees in the process of idea generation. It would be helpful for the organizations to incorporate the system of 'suggestion scheme'. Alternatively, employees from all organizational levels could be included in 'brainstorming' sessions. The process is likely to speed up decision making, and would also encourage free-flow of communication between various organizational levels. This would fulfill the need for *improved communication,* particularly felt by the lower levels.

Yet another suggestion for both organizations is to implement a well organized reward system for innovations. A proper reward system must comprise different nature of rewards for employees of different organizational levels, and for different degrees of contribution to the organization. Besides, employees in an innovative team maybe rewarded for their contribution to the successful innovation. Ideally a time span should be chosen for the declaration of rewards on a regular basis.

The approach to the study of structure-innovation relationship suggested in the present research must be regarded as a basis for speculative thinking and future research. It provides a framework for further study.

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Appendix I

Strongly Disagree — Disagree — Undecided — Agree — Strongly Agree

1 — 2 — 3 — 4 — 5

1. My organisation is active in developing new products. 1 2 3 4 5
2. My organisation is in a constant effort to improve it's products through innovations. 1 2 3 4 5
3. My organisation has contributed significant product innovations to it's business sector. 1 2 3 4 5
4. Our innovative products have generated good income on sales. 1 2 3 4 5
5. I feel our new products have been successful in the market with respect to quality. 1 2 3 4 5
6. Now products of my organisation have been widely accepted and appreciated by our constomers/ clients. 1 2 3 4 5
7. My organisation is active in developing new work process. 1 2 3 4 5
8. My organisation's policies and procedures facilitate process innovations at all stages of production. 1 2 3 4 5
9. In my organisation innovations have bee encouraged at the input level also. 1 2 3 4 5
10. In my organisation, frequent efforts are made to introduce innovatived changes in the existing technology. 1 2 3 4 5
11. My organisation is also active in developing marketing innovations. 1 2 3 4 5
12. The marketing department in my organisation is under constant pressure to come up with fresh strategies. 1 2 3 4 5
13. Any product innovation by my organisation is accompanied by a new marketing strategy for that product. 1 2 3 4 5
14. By introducing new methods of advertising our organisation has earned increased revenues from the same products. 1 2 3 4 5
15. Most people in my organisation are aware that it is important to innovate in the current environment. 1 2 3 4 5
16. The environment inside my organisation encourages a high level of innovations. 1 2 3 4 5
17. In my organisation, employees have the freedom to do their work in new ways within specified limits. 1 2 3 4 5
18. I feel my organisation does not go very strictly by the rules when incorporating useful and creative ideas. 1 2 3 4 5
19. My organisation's culture provides a strong support system for innovation initiatives. 1 2 3 4 5
20. I feel the policy of openness in our organisation allows for innovative endeavors. 1 2 3 4 5

Appendix II

Interview Schedule

1. Do you think structure of an organisation can influence, or has impact on innovation by that organisation.
2. What about your organisation? Give your comments on relationship between structure and innovations, as you view it in your organisation.
3. How would you describe the structure of your organisation? You can give certain advantages and disadvantages.
4. How do you view the hierarchy in your organisation with respect to innovations?
5. Are you satisfied with the hierarchy? Is it high or low according to you?
6. How do you think it is influencing innovations in your organisation? Is it facilitating or inhibiting innovations?
7. Do you think there is a need for some change in the hierarchy, to facilitate innovations? If yes, then what are the changes that can help?
8. How do you view the horizontal complexity in your organisation with respect to innovations.
9. Are you satisfied by the Horizontal Complexity in your organisation? Is it high or low according to you?
10. How do you think Horizontal Complexity is influencing innovations in your organisation? Is it facilitating or inhibiting innovations?
11. Do you think there is need for change in the Horizontal Complexity of your organisation to facilitate innovations? If yes, then what changes do you think will improve the situation.
12. What kind of rule and norm structure do you have? Do you have clearly defined rules for everything (every activity) in the organisation?
13. How strictly are the rules followed? Is 'following rules' emphasized in your organisation?
14. Do you think Formalization has been influencing innovation in your organisation in some way? Is it facilitating or inhibiting innovations?
15. To what extent are you free to take decisions regarding your work related matters, and matters within your purview?
16. Do you think authority for Decision Making has been centralized in your organisation? If yes then according to you, has it facilitated or inhibited innovations in your organisation?
17. Are you given the freedom to do your work in new and different ways or does the work desire to be done always in a standardized way as specified by the senior authority.
18. Are you involved in discussions for important diecisions related to work and other issues of your organisation in general?
19. Do you think participation in Decision Making has a role to play in innovations in your organisation? Is it facilitating or inhibiting innovations?
20. Are you free to express your ideas to all levels, even higher levels in the organisation?
21. Are your ideas considered and incorporated if found useful?
22. Do you think Technology Complexity plays a role in innovation in your organisation? Does it facilitate or inhibit innovations?
23. How Innovative do you think your organisation is?
24. Which departments do you think are the most innovative?
25. Which departments are the closest to customers?
26. Do you think departments which are in closest contact with customers are more innovative than departments which are in less or no contact with customers?
27. Can you recall some of the significant innovations, big or small, which have taken place in the past 5 - 7 years in your organisation, could be at input, throughput or output level, in any department.
28. Which are the structural components which contribute most to innovations at output level?
29. Which are the structural components which contribute the most to innovations at throughput level?
30. Which are the structural components that contribute the most to innovations at input level?

□

Learn everything you can, anytime you can, from anyone you can—there will always come a time when you will be grateful you did.

– Sarah Caldwell

Feature

Applying Socio-Technical System to Organization Design: A Critical Perspective

Koustab Ghosh & Sangeeta Sahney

The socio-technical system theory occupies an important place in the literature of organizational analysis and design. Frequent interactions with the environmental externalities led to organizations adopting an open system perspective. The critical components to the development and design of the socio-technical system have been reviewed in this article and industry-wide applications have also been cited to illustrate the usefulness and span of the theory.

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Socio-technical system is an established methodology that provides a structured approach to redesign of processes (Pasmore & Sherwood, 1988; Taylor & Felten, 1993; Fox, 1995; Eijnatten, 1998). It holds that every process has both social and technical sub-systems. The technical sub-system is comprised of the structures, tools, procedures, and knowledge necessary to perform the work (Fox, 1995). The social sub-system includes attitudes and beliefs, contracts between employers and employees, reactions to work arrangements, and the relationships between individuals and among groups (Pasmore & Sherwood, 1988).

The social sub-system emerges through people working within a particular work setting (Eijnatten, 1998). The 'joint optimization' of the technical and social subsystems constitutes the efficiency of the total work system. Joint optimization suggests that to effectively redesign a process, a balance must be struck between the techno-logy and the people using the technology (Shani et al., 1992). Although, the socio-technical perspective recognizes that true optimization of a complex socio-technical system is difficult to achieve, nonetheless both social and technical sub-systems must be considered for effective process designs.

The term 'socio-technical system' was coined by Eric Trist (Trist & Bamforth, 1951) to describe a method of viewing organizations, which emphasizes the interrelatedness of the functioning of the social and technological sub-systems of the organization in relation to the environment in which it operates. Socio-technical analysis owes its origin to the Trist and Bamforth study of coal mining methods in Durham. The post-Second World War period was characterized by enormous expansion of manufactured goods, urgently required and in large quantities. This prompted the use of new technologies, for

instance, in coal mining. The "longwall" technology based on extensive division of labour and hierarchical power structure in British coal mines failed to achieve the calculated benefits. It provided the opportunity for research, which led to the formation of the socio-technical model. The social part of the model encapsulates the decentralized decision-making based on competence (Trist & Bamforth, 1951). The operationali-zation of the model implies the functioning through semi-autonomous work groups and multiskilling, now associated with team working in flat organizations.

The socio-technical model was formulated and later, comprehensively developed by Eric Trist, Fred Emery, and a group of researchers at the Tavistock Institute of Human Relations, as a result of extensive fieldwork in a number of British coal fields. They found that new technological designs could not achieve maximum results on their own by being separated from the human component with which they have to interact. The technology and the people have to be treated as being coupled within a system. Out of these considerations evolved the concept of joint optimization of the social and technical sub-systems (Trist & Bamforth, 1951; Trist et al., 1963). The Tavistock researches were concerned with the social and group adaptation to production processes. The conceptualization of production processes as 'socio-technical systems' led to 'joint optimization' and subsequent generalization to other work places. The systems theory of organization holds a holistic perspective and highlights the critical interdependencies among sub-systems. Autonomous work groups as a facilitator of production systems, was the outcome of the 'control of variance' under the socio-technical principle.

"The fewer the variances that are exported from the place where they arise, the fewer the levels of supervision and control" (Cherns, 1976, p.318). Work groups, which can control their own activities within the boundaries of their responsibility, have been referred to as 'autonomous' in the socio-technical system literature.

The social system of an organization is comprised of the people who work in the organization and the relationships among them (Trist & Bamforth, 1951; Emery, 1959, 1962; Trist et al., 1963; Pasmore, 1978). Broadly, the social system includes the profile and expectations of organizational members, patterns of supervisory-subordinate relationships, interpersonal relationship of employees and the nature and interaction of sub-groups within the population. The socio-technical system theorists contend that the needs which people bring with them to the workplace, have to be identified and ways have to be made to meet those needs through the design of the technology and the work. It directs and moves the efforts of organizational members toward organizational goals. The technical system of an organization consists of the tools, techniques, procedures, skills, knowledge and devices used by members of the social system to accomplish the tasks of the organization (Trist & Bamforth, 1951; Trist et al., 1963; Emery, 1959; Woodward, 1958; Thompson & Bates, 1957).

The technological configuration chosen by organization designers effects the operation of the social system by shaping the behaviours required to operate it. The level of variety, challenge, feedback, control, decision-making and integration provided for social system members is largely a function of the way in which the technology is arranged (Fullen, 1970; Davis & Taylor, 1979; Davis, 1979).

By the late 1960s, a large amount of research and experiments had begun so that the principles of the socio-technical work design could be articulated. The core principles to the approach include: rules should be specified at the minimum necessary level, variances be controlled at the point of origin, multi-skilled workforce, role interdependence within the same departmental boundaries, and information support system to the point of action and problem solving (Cherns, 1976; Hanna, 1988). The socio-technical design led to the heavy use of teams, empowered to manage their own work processes and flows, to manage interdependent work. 'Autonomous work teams' became popular in Europe during the 1970s.

Interface of socio-technical system and environment

Organizations interact with their environments to survive. The open system perspective implies the need to examine transactions with the environment, adapt to environmental changes, and build flexibility into the organization to respond to both anticipated and unanticipated changes (Clark & Krone, 1972; Haberstroh, 1965; Emery & Trist, 1965; Emery, 1959). In the context of socio-technical systems, the open system perspective implies that the social and technological sub-systems must be designed not only for relational synthesis, but also to present and future environmental demands.

There is the tendency to equate the 'social system' correlatively with immediate task groupings, thereby subsiding the issues like occupational or union affiliation, or wider class orientations (Goldthorpe,1967). In effect, the organizational analysis of socio-technical system fails to consider any underlying structural constraints, either in the wider society or in the economic context. Similarly

under 'technical system' the focus is on machine systems and layouts that maximize the perceived discretion of management. But the same fails to appreciate the other levels of technology, including generic designs and wider networks of experts and suppliers (Scarbrough & Corbett, 1992).

During the 1960s and 1970s, organization researchers held that effective work system design needs to start with an 'open system' perspective, considering the external stakeholders (customers, suppliers, competitors). Work system design should start with an understanding of environmental requirements, demands, and opportunities and then move to the design of specific elements of the social and technical systems (Lawrence & Lorsch, 1967). The socio-technical system was usually described as an open system with boundary roles that have to be sensitive to the external environment. However, the environment was always seen as a dynamic and acting on the organization and not the reverse (Emery & Trist, 1973). In the socio-technical open systems model, the boundary role has a dual responsibility. Apart from managing the intra-organizational priorities in relation to changes in environment and market conditions, it also has to adapt, control, and monitor the organization's impact on the environment.

The purpose and goal of the system in relation to its environment assume a central place. The prime goal of an organization is to create value for its customers within certain resource and environmental constraints. Both management and unions in many countries have realized that strategy and business ideas must be understood and accepted as a key basis for action at all levels in the organization. The goal development for production groups in Swedish industry is not only changing in terms of clarity and distinctness but also in terms of its content. At Volvo, the new term is DQE-groups, which have responsibility for precision in deliveries, quality, and economic results in terms of cost control. In some cases, the business goals for groups have been efficiency-oriented. In ABB, considerable and successful efforts have been made to give the production workers responsibility for reducing the capital tied up in work in progress and in stocks. They are also responsible for planning production and scheduling orders. Other cases have involved groups in meeting and formulating goals that are effectiveness-oriented. Groups at Bord nd Mona have financial responsibility for constructing their budgets, planning production, and achieving positive results.

Design of a socio-technical system

The classical school of management theorists (Luther Gulick, Lyndall Urwick, Frederick Taylor, Max Weber) between 1900 and 1940 held that effective organizations should be highly structured with a hierarchy of authority, specialized differentiation of functional tasks, and rules and regulations specifying functional roles and relationships. This classical form of management system is known as 'mechanistic'. At the other end is the human relations school represented by proponents such as Elton Mayo, Fritz Roethlisberger, William Dickson, Lester Coch and John French, which has its origin in the Hawthorne experiments in 1927. The approach emphasized on participation of lower level members in decision-making, and greater flexibility of functional roles and relationships. It came to be known as the 'organic' system of management.

In the socio-technical system, task structures are to be seen as the connecting points between the production technology and processes at the one end, and the personnel or labour force at the other (Zwaan & Molleman, 1998). The design of the social system provides the support and sustenance to the organization. They reinforce the desired behaviour of organizational members and must help individuals to perceive a kind of linkage between their needs and organizational goals. The design of the system is an extended social process and shaped by a range of social patterns over time. People using the new system interpret it, amend it, manage it and make necessary adjustments to fit them. This implies the attempts by users to take ownership of and control over the systems. Wider social factors influence the design considerations, and the kinds of design solution that are offered as part of the system. There are always choices, in the design of socio-technical arrangements, and in the processes through which they are designed (Klein, 1994). This was one of the initial points made by Cherns (1976). Key choices include how the overall system will operate, how the work will be managed and organized, what form of technology will be required to support this work, and what other organizational policies are required to manage and facilitate the implementation process.

Fred Emery defines the dimensions of the technical system as the nature of the material worked upon, the level of mechanization or automation, the unit and process operations, the maintenance and supply functions, the spatial layout and spread of the process over time, the physical work setting and the nature of interdependence among tasks. All these dimensions impact the nature of roles and role relationships, the level of productivity and the quality of work life. The dimensions of the social system include occupational roles, role integration into teams around tasks, the nature of coordination and control, the boundary management, the degree of

delegation, and the degree of reliance on the expertise of workers in making complex judgments and decisions.

The 'nine-step model' for socio-technical analysis developed by Emery include initial scanning, identification of unit operations, identification of key process variances and their interrelationships, analysis of the social system, people's perceptions of their roles, analysis of the maintenance system, analysis of supply and user systems, analysis of the work environment and any proposed development plans and proposals for change.

Using examples from Philips Electrical Industries, General Foods, Shell, Corning Glass and Sony, Eric Trist points out that the mandate from the top is not sufficient to produce systematic change in the organization. Individual job designs that support learning and participative involvement of workers bring about change. Technology to be employed depends upon a thorough analysis of the nature of inputs, the specification of outputs, the process operation, in-built regulatory mechanisms, and control of variations and tolerance limits. This diagnosis then moderates the design of the social system in terms of choice, control and span of boundaries, job content, task autonomy, group relations and organization structure. The production structure is first redesigned into 'whole tasks', and then 'whole-task groups' (self-organizing teams) are assigned to each of these tasks (de Sitter et al., 1997). In relation to the self-organizing groups, both the production environment and the production system must be carefully considered.

So also in terms of the work force, the firm's policies regarding training and development, recruitment, promotion, appraisal, career opportunities and remuneration must be aligned with the principle of self-organization. The problem for the designer is how to structure the technical units, the information and feedback, and the kinds of activities people have to undertake for rapid adaptation and learning needed to adjust to the unexpected demands from the environment (Davis, 1979). Many designs of alternative organizations, particularly at the level of jobs, incorporate various attempts to provide better security, equity, and rewards, and to satisfy the growingly articulated psychological needs of all who work (Davis, 1975; Englestad, 1972). The principles for socio-technical systems design should include, compatibility, variance control at source, multifunctionalism, boundary location, information flow, support congruence, articulation of human values and continuous process adaptations (Albert Cherns, 1978).

The impact of socio-technical demand on work and organizational outcomes has been the subject of extensive research at the macro-level (Eason, 1988; Gillespie & Mileti, 1979; Woodward, 1965). Recent research into socio-technical systems has shown significant potential for understanding the dynamics in industrial organizations, and for providing management some guidelines for effective organizational design. The evidence indicates that a contingency model of management systems and technological conditions has potential for designing effective organizations. Persons responsible for policy making must understand the socio-technical imperatives.

The work system should be conceived of as a set of activities making up an integrated unit, rather than a mere collection of individual jobs. The work group should be considered as more central rather than individual jobholders. The internal regulation of the work system is preferable to external regulation of individuals by supervisors. The design principle should be based on integration of functions rather than on differentiation of parts. Both prescribed and discretionary components of work are important to the functioning of the system. The individual should be viewed as complementary to the machine, rather than as an extension of the same. The design of the work should be based on a variety of components on an increasing basis.

Principle of Joint Optimization

A B Cherns pointed out that the system approach requires both design elements and design process to be congruent. The same is often referred to as joint optimization of technical and social systems in the literature of socio-technical systems theory. Socio-technical systems theory takes the fundamental premise that organizational objectives are best met by joint optimization of the social and technical systems (Cherns, 1978:63). In optimizing the social and technical systems, key organization design principles are engaged, including minimal critical specification and support congruence (Benders, 1993; Cherns, 1978; Hyer et al., 1999).

The principle of 'joint optimization' (Emery, 1959) states that an organization will function optimally only if the social and technical systems of the organization are designed to fit the demands of each other and the environment. In contrast, many techniques aimed at improving organization effectiveness concentrate on the social system exclusively, taking the technology of the organization as constant and unchangeable (Friedlander & Brown, 1974). Instead, people and technology within the organization have to be integrated for the benefit of the other. The purpose of the socio-technical intervention is to redesign the sub-systems to improve organizational performance and enhance the quality of work life.

The socio-technical perspective explicitly narrates the idea that all aspects of a system are interconnected and they should be designed jointly. Technical and social systems are interdependent. Exclusive emphasis on any one component will be sub-optimal (Klein, 1994). Some of the interdependencies may not be apparent during system design. The designers of some new technology may not be able to anticipate the impact of their design efforts on other aspects of the system and find it difficult to plan changes that make their operation consistent. System designers and planners should make efforts to identify the possible impacts of designs across a broad range of system performance requirements.

Analysis of a socio-technical system

Organizations comprise a number of core processes that are spread over laterally across different functions. It is important to design integrated processes and a job should comprise a whole task, rather than a fragmented part (Hackman & Oldham, 1976). People should be responsible for supervising and managing complete processes. They should have the authority and resources to do a job. The information systems should be designed to match this perspective (de Sitter et al., 1997). Processes should be simplified to take out unnecessary activities, repetitions and delays. The holistic process perspective can make considerable improvements in performance. Socio-technical system involves the allocation of tasks between humans and machines. Well-established criteria exist for the design of jobs in the system (Emery, 1964; Cherns, 1976; Hackman & Oldham, 1976; Warr, 1987; Medsker & Campion, 1997). Criteria also exist to allocate tasks between humans and machines (Fitts, 1951; Grote et al., 1995; Sharit, 1997; Beevis & Essens, 1997;Older et al., 1999). The socio-technical perspective provides inputs to people working in different roles and disciplines so as to collaboratively design work within the system. It becomes imperative to consider the extent to which the new system is integrated with the existing design and requires close coupling with articulated design methods and approaches (de Sitter et al., 1997). The consideration of human factors under such an integrated design process extracts commitment to the organization on important issues (Lim et al., 1992).

The technological demand at the task level is represented by: (1) The depth and complexity of the search behaviour of the workers to complete the task; and (2) The variety of the problems that may lead to search behaviour along with the number of exceptions encountered by the workers (Perrow, 1970). Social demand at the task level is found in the need for peoples' participation in an ongoing set of human interactions by which they influence each other, learn and internalize organizational values, and integrate their activities within the work system (Cummings & Srivastva, 1977). The socio-technical model thoroughly scrutinizes the social component in the design of the system. Optimization decisions cannot always be reached easily. But the socio-technical model offers the possibility of some kind of integrated solution that avoids attempts to overweigh one or two factors at the cost of the others.

Taking a system perspective, Fred Emery suggests that splitting of work creates an inability to control the system as a whole. Because the system seldom operates perfectly, even small problems can create large systemic impacts. Taking the illustration from Volvo, he proposes that 'the basic unit for design of socio-technical systems must itself be a socio-technical unit and have the characteristics of an open system'. This implies a small self-managing work group that possesses the skills and authority to control the operation of their technology and processes. The technological and social demand shouid be positively related. Charles Perrow (1970) noted that organizational structure must be congruent with the predominating technology for the organization to be successful. Non-routine types of firms will perform best with an organic structure and firms working on a routine type of technology are best structured mechanically. Lawrence and Lorsch (1969) present that collaboration in the form of unity of effort is required among departments in response to the demands of uncertain environments. Integration can be achieved through methods ranging from the mechanistic control and scheduled procedures to organic processes requiring considerable interpersonal and conflict management skills on the part of individual organization members (Lawrence & Lorsch, 1969). As technological demands become more complex, social demands also increase. Recent work by Homer-Dixon (2000) points out that behavioural imperatives of the work system are critical prerequisites to technical efficiency and it will require investments of greater degrees on developing adjustment skills. A socio-technical system as an approach to job design also emphasizes on training and development of the workforce.

Application and implications

Eric Trist and others viewed that the behaviour could be influenced by the context in which it was observed. The socio-technical perspective was a natural outcome of this view in cases of manufacturing and mining. Later, the understanding of the effects of different socio-technical system arrangements resulted from studies at the Glacier Metals Company and the British coalmine industry. Then the context of behaviour was extended beyond

the workplace to include interorganizational relationships, then to communities and finally to the society as a whole. The studies at these different contextual levels revealed that changes in social and interorganizational relationships led to more flexible and participative forms of organizations. Subsequently, Fred Emery added that an individual job in the socio-technical system must have an optimal level of variety, learning opportunities, some scope for making decisions, organizational support, social recognition and the potential for a desirable future. Since the introduction of the socio-technical system (Trist & Bamforth, 1951), it has undergone multiple changes and evolved as a redesign methodology. The most well known development of socio-technical principles appears in the work of Cherns (1976, 1987). Taylor and Felten (1993) provided additional socio-technical design principles.

During the 1960s, socio-technical design was applied to larger work systems, in particular, complete manufacturing installations. Notable examples are the General Foods Topeka dog food plant, and the Volvo Kalmar assembly plant in Sweden. By the late 1970s, several hundred new plant designs had been implemented in the United States with a very high success rate (Lawler, 1978). The new plants also reflected significant changes in the design of the organizational architecture, the formal and informal structures and processes that formed the core work process (Lawler, 1986). The new plant designs continued to apply in organizations like Digital Equipment facility in Enfield, Connecticut, and the Procter & Gamble technician plant in Lima, Ohio. During the 1980s, a growing number of companies began to integrate the socio-technical, open systems into an approach called high-performance work systems as a logical extension of the earlier frameworks (Nadler & Gerstein, 1992).

In the 1980s, attention to unit operations and the interdependencies among technical processes have been reinforced by the reengineering approach. Empowered, multiskilled, small-sized, autonomous work groups are the order of the day. Socio-technical design principles have served as a foundation to guide process redesign. It has been applied in manufacturing (Taylor & Felten, 1993), computer operations (Taylor, 1986), healthcare (Chisholm & Ziegenfuss, 1986), nursing (Happ, 1993), information technology (Shani & Sena, 1994) and office technology (Pava, 1986). It has been observed that many process-reengineering approaches partially draw on socio-technical system thinking and methods for redesign (Mumford, 1995; Jaffe & Scott, 1998; Cheyunski & Millard, 1998). The reengineering approach has ignored the socio-technical systems and focused almost exclusively on the technical aspects of work (Nadler & Tuhman, 1997). The initial work of reengineering was inconsiderate to the impact of human elements (Loh, 1997). Therefore, a holistic reengineering methodology was prescribed to include the analysis of human elements in the process (Keating et al., 2001). The socio-technical systems approach has application to non-industrial organizations also as hospitals and schools.

In case of information technology, the focus is shifted from mechanical pacing of work to the human implications of information flows and communication systems. To respond to such a system, we need to reinforce on the social construction of technology. The internal ordering of organizational knowledge and technical expertise plays important role in shaping both the design of technology and the way in which it is integrated with the social structures of the organization (Whipp & Clark, 1986). Cal Pava (<MI>Managing New Office Technology<D>, 1983) holds the application of socio-technical systems thinking in all kinds of non-routine work. Information systems play a supporting role in the analysis and design of systems through various forms of human interactions. Gareth Morgan (<MI>Organizational Choice and the New Technology<D>, 1989) considers the joint optimization in relation to the microprocessor revolution and points out that the human adjustments determine the acceptability and success of the new technology.

The behaviour cannot be understood without considering the context in which it happens. Increasing complexity demands a more democratic form of organization. Well-designed and fully trained teams are capable of responsible self-direction. A design based on integration of functions facilitates such autonomous work groups. Adaptation to changes requires flexibility in roles and job descriptions. Changes at the core work require changes in supporting systems as well. The boundary management is critical to sustain high performance. Organizations must develop evolutionary competence, which permits design arrangements to change as the system matures. (Pasmore, William A., 1978). The interdependencies that exist among organizations in different sectors make the open system perspective more important. To integrate the concerns of diverse and conflicting stakeholders have become apparent across a wide span of organizations.

Conclusion

The needs, skills, abilities, aspirations, and social values brought by individuals into the work place have been ignored by classically structured organizations and in many cases has been a major cause of malfunction. Classical organizational design fits people into the technical system to support and perform certain activities to

best serve the process requirements. Lisl Klein (1994) observes that social scientists and industrial engineers have avoided collaboration in the design of work systems. He contends that collaborative efforts must become institutionalized through policies, procedures, methods and infrastructures. Industrial engineers focus exclusively on the design of the technical system in the belief to enhance the organizational performance. The previous researches and surveys show that in many organizations, various schemes and ideas are imported to fit the requirements of the technical system. But such imported schemes and ideas fail to fit the social system of the organization and subsequently, the performance declines as a result of sub-optimization. In the face of rapid changes, organizations are consciously adopting a system view of internal organization and its relations and responses to the external environment. Structure of organization, content and scope of roles, reward systems, design of technology, and functions of social systems should be such that organizational units can carry on without external coercion. Individuals or groups should be provided with the requisite response capabilities and authorities to regulate and control variances or disturbances without any external interference to achieve the desired objectives, so that, they can become self-regulating (Davis, 1977).

Despite the emphasis on system thinking and open organization-environment interface, socio-technical applications have tended to become isolated. Systematic diffusion even within a division of a large company has often been slow and problematic. Union or top management resistance, economic conditions, turnover among key personnel, rapid changes in technology, lack of cooperation on the part of group or units have often been found as roadblocks. Socio-technical intervention has not succeeded in obtaining the support for universal applications like total quality management (TQM) and business process reengineering (BPR). Notwithstanding the rich contributions of Boon, Levin, Sapir, and others, methods of social analysis have been found to be inadequate. Various methods including, role network analysis, evaluating individual job characteristics, and surveys of attitudes or opinions, have been tried and tested. None was able to capture fully the complexity of the multiple dimensions of behaviour and the associated influences in the form of work systems. Methods under socio-technical systems interventions that allow more speed, greater ownership, and more complete understanding of design options need to be explored (Pasmore et al., 1982).

Continuous changes and innovations are taking place in technologies. So also, there are changes in peoples' values and expectations. Keeping this in mind, one of the major challenges that the organizations face today is to strike a balance between these two changes to operate at an optimal level. There exists a latent need for socio-technical researchers in terms of conceptualizing today's problems, developing and revising the theories, tapping and incorporating new variables into analysis, and resolving the issues of organizational integration in various industries. The socio-technical systems research needs to be adapted and contextualized in the present organizational requirements with special attention to the design and use of information technology and the process outsourcing.

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The evidence shows that, on average, it required five workers in the LDCs to produce what one worker produces in other developing countries, and 94 LDC workers to produce what one worker produces in developed countries in 2002-2003. Worse still, the productivity gap is widening.

– UN Conference on Trade and Development

Feature

Online Higher Education in Developing Countries: Need for Technology Infrastructure Development

Arabi U

Online higher education initiatives emerge in different shapes and forms, from complete new virtual universities to traditional institutions using the Internet to complement their services. This paper addresses the educational policy process by analyzing the use of the Internet in the provision of the higher education market, pointing out the current drivers behind the development of online distance higher education. It also reviews the status of the technology market and of the legal framework in which online higher education can operate, and presents some recommendations for developing countries.

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The content as well as influence of education on society and the methods of education have undergone momentous changes to meet emerging needs in terms of knowledge and numbers. Currently, education is potentially one of the key sectors where information and communication technologies (ICTs) are applied. The opportunities presented by ICTs to change the content of and approach to learning as well as to extend the reach of educational institutions, could have a profound effect on development (UNCTAD, 2004).

The provision of education results from a combination of policy action and market processes, within the context of any given economy and society. Distance education, structured learning in which the student and instructor are separated by time and place, is currently the fastest growing form of domestic and international education. What was once considered a special form of education using non-traditional delivery systems, is now becoming an important concept in mainstream education (Marina Stock Mclsaac, Charlotte Nirmalani Gunawardena, 1996).

Due to the rapid developments in technology, courses using a variety of media are being delivered to students in various locations in an effort to serve the educational needs of growing populations and also allow distance education programmes to provide specialized courses to students in remote geographical areas, with increasing interactivity between student and teacher. Besides, most distance learning programmes rely on technologies that are either already in place or are being considered for their cost effectiveness. Hence such programmes are particularly beneficial for the many people who are not financially, physically, or geographically able to obtain traditional education.

Distance education has evolved from early correspondence education using primarily print-based materials into a worldwide movement presently using various technologies of delivery. Print materials, broadcast radio, computer conferencing, e-mail, interactive video, satellite tele-communications, and multimedia computer technology are all used to promote student-teacher interaction and provide necessary feedback to the learner at a distance.

Technology and delivery systems have been so crucial to the growth of distance education. Recent developments in interactive multimedia technologies also have the capacity of creating new environments for learning as "virtual communities". Online higher education, which involves the dissemination of, access to, and exploitation of higher education, including research, via the Internet, is being explored and promoted as a strategy to provide further access to education and technology for national and international students. It is also being used to promote ICT skills, provide additional revenues and enhance the competitiveness of institutions and individuals, at both the national and the international level. For example, in India students are able to obtain via the Internet a bachelor's degree in information technology (IT) from the Indira Gandhi Open University (IGNOU). IGNOU is building on its existing structure as a distance education provider. With a $200,000 budget it is providing online education to 10,000 students, with some content developed in-house and some bought from a provider in the United Kingdom. Through international collaboration, the instructor and other students on electronic mail or face-to-face according to their needs around the world, participate in cooperative learning activities and in sharing of information through the use of computer networks (Riel, 1993).

In such cases, global classrooms may have participants from various countries interacting with each other at a distance. Many mediated educational activities allow students to participate in collaborative, authentic, situated learning activities (Brown & Palincsar, 1989; Brown, Collons & Duguid, 1989). In fact, the explosion of information technology has brought learners together by erasing the boundaries of time and place for both site-based and distance learners, thus allowing students to study in any place at any time. As a result of these developments, although early research was centered on media comparison studies, educators currently have become more interested in examining how the attributes of different media promote the construction of knowledge (Salmon, Perkins, & Globerson, 1991). It is within the theoretical framework of knowledge construction and expert systems (Glaser, 1992) that some of the most promising research on mediated learning appears (Barrett, 1992; Harasim, 1993; Salomon, 1993).

Meanwhile, as emerging technologies and communications provide highly cost-effective solutions to the problems of sharing information and promoting global understanding between people, Governments and institutions in developing countries are concerned about what their role would be, and ask for possible strategies to maximize the benefits of online higher education.

The current online higher education market is still small compared with traditional face-to-face education and fragmented with multiple providers and self-developers providing flexibility, innovation and plurality. It is more established in developed countries, where a strong education system, a competitive market and ICT infrastructure are in place. These countries are also the major exporters of higher education services. In developing countries, the Internet is progressively being introduced into higher education, catering mainly to those that are able to afford it. Online programmes are concentrated in the most popular and marketable subject areas (business management, ICTs, and education) and the large majority is in English.

There are programmes like that of IGNOU around the globe – on small islands in the Pacific, in Africa, in South America and elsewhere. Online higher education initiatives emerge in different shapes and forms, from complete new virtual universities to traditional institutions incorporating the Internet to complement their services.

The strategies for adopting online higher education available to educational institutions in developing countries include customizing programmes to the local context, building on existing market presence or developing regional leadership, and/or options that exploit the experience of other institutions, such as partnerships in the provision of content and technology or in the recognition of diplomas. Investment in online higher education, whether by students, institutions or Governments, needs to be measured against other priorities and needs.

Importance of online higher education

The acquisition of literacy and numerical skills necessarily continually need updating and learning of new skills through either the corporate workplace learning or access to community education. It also extends into other kinds of cultural and leisure activities – visiting a museum, watching a television documentary, going to the theatre or reading a book. In all of these areas, ICTs – and in particular the use of the Internet – is having an

impact on why and how people access learning and what they use it for. The international trade in higher education is more relevant for national Governments. Governments have an important responsibility to overcome financial, technological and development hurdles and promote the development of an educated population. They play a key role in maximizing the potential of online higher education initiatives, and particularly in ensuring that such initiatives narrow rather than increase digital divides and support local needs and culture.

The Internet has a number of uses within education: disseminating learning content, enabling communication between students and teachers, and engaging in and publishing research. The use of the Internet for education, including the use of websites and e-mail, has come to be known as online education. Online courses frequently use the Internet in combination with other delivery modes. E-learning is a more broad notion than online learning and equally has no universally acknowledged or standard definition. The e-learning embraces every kind of teaching and learning situation using some element of electronic or digital resourcing (radio, audiocassettes, videocassettes, TV, personal computers, e-mail, Web) and considers online education a subset of e-learning. On the other, blended learning is learning that combines different modes of student engagement. In practice, the use of blended learning has been limited to the combination of online learning with face-to-face instruction.

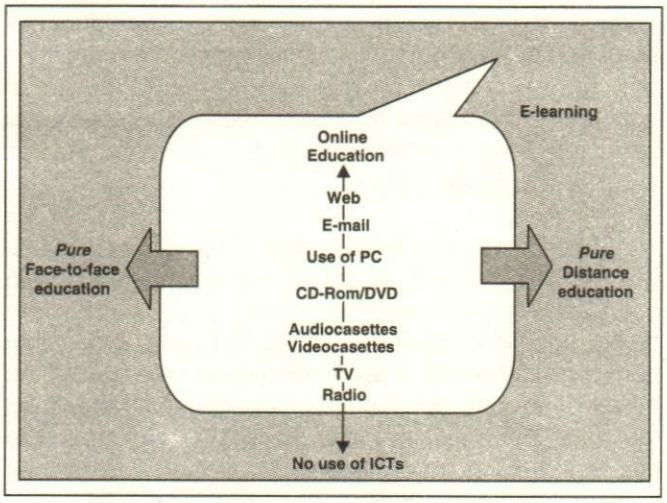

Chart-1: The E-Learning Continuum to Online Education

Main drives of online higher education

To develop educational capacity

The Internet makes it possible to reach more people over a wider area with limited access to traditional education in general or to specific higher education institutions. In this sense, online higher education is an extension of the distance learning model. The arrival of the Internet has brought additional access at a distance in the sense that most traditional and well-known universities did not engage in distance education, whereas they may do so now through online delivery.

To improve the quality of learning

There is a strong argument that the use of ICTs can increase the effectiveness and quality of learning by providing increased customization, more flexibility and student choice. In fact the pedagogical benefits of e-learning include: (a) it promotes the development of skills and attitudes, in addition to subject area knowledge; and (b) it offers students the possibility of extending their learning (via links, databases, etc.). However, teachers, students and employers have long contested the quality of online education, and there is a widespread perception that online degrees are of a poorer quality than those based on traditional study. In contrast, as part of a wider lobby promoting the values of ICTs and the Internet, there are groups, within both the educational and the IT community that assert the value of e-learning in raising educational standards and effectiveness.

To increase access for marginalized populations

E-learning can be used to provide innovative solutions to address specific access issues that might make it difficult for potential students to participate in higher education. For example, the University of Palestine has attempted to use an element of online learning to enable students to interact with tutors when they are physically unable to reach the university because of roadblocks and other security measures in Gaza.

To achieve cost-efficiencies

The possibility of e-learning to expand capacity and access brings with it potential cost-efficiencies (reaching more students for less money) through reducing the cost per unit (or student) and therefore improving an institution's financial position. For many developed country institutions whose budgets have been reduced and which are facing increased domestic competition for funding, the potential to expand their market globally through virtual campuses and other e-learning ventures has been a strong driver. However, the argument that online education provides economies of scale, and thus cost-efficiencies, is contested. Depending on the infrastructure available, the initial start-up costs may be high and, if quality is to be maintained, the cost reduction per addi-

tional student numbers will be minimal. Thus, investing in online education solely for the sake of cost-efficiency is a high risk for any provider. In addition to economies of scale, the application of ICTs to education does provide other potential economic.

To enhance ICT skills and infrastructure - to promote a knowledge economy

Perhaps the key driver for online education at the macro-policy level is that it will enhance ICT skills and infrastructure, and thus serve to reinforce the promotion of a "knowledge economy". Developing an e-learning strategy can complement other national ICT policies. Indeed, there are synergies between different sectors. For example, in the United Kingdom, the Department of Trade and Industry has targeted educational and training services – in particular online education – as a key area for overseas export. One of the potential benefits for Governments in adopting an e-learning strategy is that it can promote the use of ICTs and contribute to the development and use of ICT infrastructure. It can also provide a market for related industries, including software, content development, media and other educational services.

In today's globalized information society, falling behind in access to and use of ICTs (digital divide) can lead to losing economic and development opportunities and can exacerbate existing inequalities between and within countries. To overcome this digital divide, it is necessary to develop ICT infrastructure and skills as well as an understanding of the appropriate use and application of ICTs relevant to different needs and contexts. However, unless underserved populations (including rural, women, disabled and lower-income students) are consciously and proactively targeted, any national digital divide will increase. Using online education to bridge the digital divide is an attractive proposition, but it will only happen if a coherent inclusive strategy is put in place together with the necessary resources. Partnerships with private enterprises can partially alleviate resources restraints.

Currently, international donors, private enterprises and other players have a strong interest in investing in online education. In the information society, information obviously has essential value. Economies are increasingly dependent on both the information that is available to them and the resources with which to use it. But for this information to be valuable, it has to be relevant to the user, and to the latter's context and purpose. This applies to every user, from the savvy IT student to the basic reader, for every context, from the international market to a small rural community, and for every use and sector from services to agriculture. One of the concerns about the proliferation of online education is the dominance of developed countries in producing and disseminating content and information: most Internet content is in English and originates in developed countries. The effects can already be seen: citizens are unable to access relevant information because it is in a language they do not understand; and it is irrelevant to their context and incompatible with their existing level of technology and skills. Given that professional content is largely created and shared through universities, online higher education offers an opportunity for national Governments interested in devoting efforts and resources to the creation, promotion and use of local content. New initiatives such as open content and open source are putting in place some of the necessary frameworks for the open sharing of information.

In addition to the above drivers of online higher education, the economic and cultural rationales for a Government to promote online higher education also are included: (i) the belief that it can help bridge the digital divide, within and between countries, and (ii) the desire to promote local content for domestic use and for export.

The online higher education market

The online higher education market comprises of goods and services that include software applications that enable interaction via the Internet, course content, support services (such as accreditation or education management) and the actual dissemination of education (e.g. the interaction between teacher and students). In addition, online higher education requires products not restricted to the specific online higher education market, such as ICT infrastructure.

Table 1 presents an overview of the different stakeholders and interests in online higher education. With online education new stakeholders have entered the higher education market (such as ICT providers – both of infrastructure and of applications), and the bargaining power of existing stakeholders has changed. Potentially, teachers are losing influence to software developers who create structures and systems for teachers to fit their content into. Some students can have increased power because they can now choose among different educational providers, even without leaving home.

The Economist Intelligence Unit ranking (2003) grades 60 countries on their ability to produce, use and expand Internet-based learning – both informal and formal, at work and at school, in government and throughout society. This ranking assesses e-learning on the

Table 1: Framework of e-learning in higher education: Main uses and stakeholders

Areas of investment Stakeholders with examples	ICT infra-structure	Course delivery and administration	Content and ICT applications	Accreditation services	Students(Fees, subsidies)
National Governments E.g: UK	X		X	X	X
Public university E.g: Indira Gandhi Open University	X	X	X	X	X
Private universityE.g: Univ. of Monterrey	X	X	X	X	X
ICT Infrastructure/telecoms sector E.g. Cisco	X				
ICT applications sectorE.g: Web CT	X	X	X	X	
Media and publishing E.g BBC			X		
University staff Professors and support		X	X	X	X
Students as Consumers				X	X
Educational Services providers, e.g: Ed Excel		X	X	X	
International CommunityE.g: donors/foundations	X	X	X		X

Source: UNCTAD-2004, E-commerce and Development Report, pp-104

Table 2: E-learning readiness ranking, 2003

Country	Score (of 10)	Rank	Country	Score (of 10)	Rank	Country	Score (of 10)	Rank
Sweden	8.42	1	Italy	7.07	21	Romania	4.91	41
Canada	8.4	2	Spain	6.98	22	Venezuela	4.82	42
United States	8.37	3	Japan	6.53	23	Philippines	4.8	43
Finland	8.25	4	Greece	6.52	24	Russia Fed.	4.65	44
South Korea	8.24	5	Malaysia	6.48	25	India	4.56	45
Singapore	8	6	Israel	6.34	26	China	4.52	46
Denmark	7.98	7	Portugal	6.33	27	Saudi Arabia	4.5	47
U K	7.93	8	Chile	6.13	28	Ukraine	4.38	48
Norway	7.91	9	Czech.Rep	6.11	29	Ecuador	4.38	48
Switzerland	7.72	10	Hungary	6.09	30	Turkey	4.33	50
Australia	7.71	11	Mexico	5.96	31	Egypt	3.98	51
Ireland	7.6	12	Argentina	5.86	32	Kazakhstan	3.79	52
Netherlands	7.59	13	Poland	5.73	33	Indonesia	3.67	53
France'	7.51	14	Brazil	5.63	34	Azerbaijan	3.67	53
Austria	7.49	15	Slovakia	5.51	35	Sri Lanka	3.66	55
Taiwan P. C	7.47	16	Thailand	5.11	36	Algeria	3.52	56
Germany	7.45	17	Peru	5.1	37	Viet Nam	3.32	58
New Zealand	7.37	18	Colombia	5.05	38	Pakistan	3.22	58
Hong Kong (China)	7.34	19	Bulgaria	5.04	39	Islamic Rep. of Iran	3.06	59
Belgium	7.19	20	S. Africa	4.96	40	Nigeria	2.82	60

Source: Economist Intelligence Unit (2003)

basis of four categories: education (Internet access and use among teachers and students, including equality considerations), industry (use in different sectors), and government (its support for e-learning) and society (populations' access to and use of the Internet, including attitudes and overall level of education). Within each category the assessment is based on four factors that make e-learning possible: connectivity – "the quality and extent of Internet infrastructure"; capability – "a country's ability to deliver and consume e-learning, based on literacy rates, and trends in training and education"; content – "the quality and pervasiveness of online learning materials" and culture – "behaviour, beliefs and institutions that support e-learning".

Although the ranking examines a broader sector than higher education, it does provide some kind of map of the state of e-learning internationally.

Much of the literature cites that for a wide range of policy reasons, such as equality motivations or ability to raise funds, financial returns in higher education are not as secure as they are in the corporate e-learning market. In Asia, online education is growing in the richer and more technically advanced developing countries. For example, in Malaysia there are two institutions playing a leading role in the regional online higher education market: UNITAR (Universiti Tun Abdul Razak), a private virtual university offering 20 academic programmes in the field of business, IT and social sciences to more than 8,000 students at 11 study centres in Malaysia, Cambodia and Thailand, and Malaysia University of Science and Technology (MUST), a private research institution set up in collaboration with the Massachusetts Institute of Technology. In contrast, India and China have a long tradition of open and distance education, with experience in the application of technologies to education, such as satellite and radio, but for the moment online higher education is only starting to be developed. In Africa there is the African Virtual University, originally created by the World Bank and now a donor-led and mixed distance/e-learning initiative.

Online higher education in many cases evolves from distance education. Open universities, such as in India and the UK, have long been using technology in a number of ways, such as radio, TV, video cassettes etc, to deliver courses at a distance. The transformation from distance to online education is a more natural evolution: instructors are familiar with teaching at a distance, the university already has a structure to develop course materials, and students are used to interacting with teachers and one another across space and time. In marketing terms, online delivery has given more credibility to distance education, which has often been seen as second best to traditional, face-to-face higher education. It seems that Governments are more inclined to provide funding for online projects than to fund distance education. For example, according to Tu and Twu (2002), in Taiwan Province of China the Government was assigning between $3,125 and $9,375 for a traditional university student, while the expenditure for a distance education student is $625. One of the trends we have seen in higher education is the growth of private providers and an increasingly blurred division between private and public provision.

In the United States, with its particular pattern of private higher education, only 4 to 5 per cent of all students are enrolled with for-profit providers. However, 33 per cent of all online students are enrolled with the same provider (Howell et al., 2003). It would seem that private for-profit interests are leading in providing online educational services. Additionally, several public institutions are providing online education through a for-profit institution, such as the failed New York University Online initiative. As in offline education, alliances between for-profit and not-for-profit organizations, and between private and public institutions, provide strategic benefits but also carry governance and sustainability risks, as well as access, equality, quality and ownership implications.

Determinants of Investment in online higher education

Profitability of online education

As with any public investment in ICTs the most substantial objections to online education is the opportunity cost of investing in ICTs rather the programmes judged to be more vital. Four criteria help determine financial decisions for investment in online higher education: profitability, affordability, sustainability and efficiency. From the point of the profitability of online education the question lies with whether it is cheaper than traditional education. An answer to such a question needs to examine the cost structure of e-learning courses. A case for economic argument for online education has to be based on economies of scale. Surely, online education is potentially cheaper than face-to-face education, in which a large number of students are targeted. Theoretically, the additional cost per student is limited, and therefore a large customer base allows the recovery of the significant investments made on infrastructure and on product development.

However, the economies-of-scale argument again depends on clear evidences; which is lacking even now; though some large-scale e-learning programmes have failed despite their aim of reaching more customers (students). For example, UNCTAD's Training for Trade programmes depend on donor funding, the content (and even the software) is developed in-house, and competition is limited to the search for donor monies. The content is highly specialized, and based on the core of the organization's knowledge. While it provides opportunities for the dissemination of knowledge, concerns about self-sustainability, particularly in an increasingly competitive environment, and because of the limits to funding (for example, if the e-learning fashion were to pass), should be addressed. Similarly, quality and customization raise doubts about any possible economies of scale for online higher education.

Maintaining an acceptable tutor/student ratio cannot be achieved cheaply without alienating teachers, and customization to local culture involves a high degree of content and pedagogical expertise that requires a significant proportion of any budget. Interestingly, while in the wider e-learning literature, reducing costs is seen as a major motivating factor for institutions, several of our respondents actually claimed that online courses were more expensive than their offline equivalents. Therefore, there are other factors that make the investment in online education worthwhile. From the individual point of view students will be assessing whether their efforts will be remunerated in terms of increased life opportunities, private institutions may look at further utilizing existing infrastructure, increasing loyalty and improving the quality of their services, and educational policy makers will be seeking to increase access and further ICT skills. Though some institutions in developed countries are enjoying returns on their investment in online education, the potential for developing countries may be more constrained. For example, online provision increases international competition for students, which in turn has an impact on the ability of institutions in developing countries to charge higher prices to non-resident students, given their low brand recognition or their catchment area.

Affordability

Affordability, or the question of whether Governments, institutions and students can afford online education, is a related issue that can be overlooked in the profitability criteria. Is the Government's educational budget able to afford the provision of online education? Would lower income students be able to access online higher education? It can be argued that the national Governments' investment in online higher education is justified when it allows the participation of students from lower-income levels. But as we saw in the introduction, online education tends to be associated with private provision, particularly in higher education. On the other hand, the capacity of international funding to finance higher education is rather limited, in terms of both time and the proportion of overall spending. Thus national Governments are entrusted with the responsibility of taking crucial financing decisions for higher education, by investing themselves and/or encouraging the private sector to invest.

Sustainability of the programme

The third major criterion is the economic sustainability of any online education programme. Governments of developed countries and international organizations, including the World Bank and the United Nations, have been actively involved in promoting new online higher education initiatives. The question arises as to what will happen at the end of the programme when the specific funds earmarked for online education have been used and the programme is handed to the local institution, and/or when the funding priorities and private investment interest shift to other areas.

Efficiency in the educational sector

ICTs increase specialization, which in turn can bring more efficiency to the educational sector by enhancing internal organization, communication and knowledge sharing, and by allowing teachers to specialize in their field of expertise. The Internet is providing new business models that promote open access to education and research information. The Internet is also allowing the unbundling of academic functions and thus specialization, as well as promoting the convergence of different educational sectors, by facilitating the reuse of educational content. This can yield new efficiencies and markets, and allow for local customization. However, unbundling can also bring with it possible loss of ownership of educational resources and processes. Additionally the efficiency of online education needs to be measured against educational objectives and context. It is clear that what is efficient in a developed economy, with an already established edict coverage, may not be so efficient for a low-income economy where the number of people with access to the Internet is much smaller.

Traditionally, the financial analysis of higher education has focused on two areas – firstly, comparing the cost of producing a course or educating a student, and secondly on analyzing individual initiatives and their profitability. Both areas of analysis cast doubts on the profitability of online learning, and although there are potential earnings with economies of scale and individual financial success stories, there have already been many failures and there may be more when donors withdraw their funds. Analysis of the three other criteria – affordability, sustainability and efficiency – is also necessary in order to evaluate the economic viability of online higher education, and in particular to enable national Governments to take sound decisions.

Requisites for the use of online technology

Technological infrastructure and applications

The use and the adoption of online higher education requires ICT infrastructure. To maximize the use of ICTs in education, computers and software are indispensable, and in the particular case of online learning access to

the Internet is also a prerequisite. Reliable and fast connectivity, as well as sufficient bandwidth, are of particular importance in order to make full use of the range of e-learning software and applications – from animated simulations used to enhance learning in engineering or medicine to video conferencing for increased interactivity between students and teachers at a distance. The ability of a region, state or nation to develop e-learning depends on the existence of a strong ICT infrastructure. The building of knowledge economies and of the related human-resource capacity also requires the availability of non-electronic information and knowledge sources (e.g. libraries, books and journals available to the public), competent educational management, a culture of change and sufficient educational funds. A corollary then is that if online education is to be successful, funding of ICT infrastructure should not be at the expense of other knowledge resources.

For stakeholders producing or providing education in developing nations the question is how best to maximize the potential of online education and the technological infrastructure available to achieve their objectives. Some providers or Governments believe that the only way forward is to increase connectivity or improve access to new technology. However, others, particularly local developers and providers, defend the use of low or intermediate technology or concentrating access provision in community or distance learning centres, such as the ones used by Indira Gandhi Open University.

Content production, delivery and course management

The Internet has had a major impact on education in terms of both content creation and distribution. Digital technology has facilitated the creation and distribution of content, but the Internet is also allowing wider access to these tools so as to create and share knowledge through global resource exchange and instant/distant content discussion. What follows is an examination of the structures and products that support online content creation, delivery and management. Designers and teachers use a wide variety of tools to create content, such as word processors, presentation software, audio, video and animation. They also use ICT tools to evaluate students (e.g. assessment tools). Moreover, they use ICT-based communication to enhance teacher–student or student–student interaction. Traditional methods, such as audiocassettes and videocassettes, are and will continue to be widely used in developing countries.

Obviously, the creation and delivery of content requires course management, and vice versa, and both are reliant on the infrastructure available. For example, distributing content through videoconference will only be possible if the intended audience has access to videoconferencing equipment as well as the knowledge and motivation to use it. Educational materials for online education are normally referred to as courseware, and learning objects are the modular units of instruction that can be stored and searched through data bases and networks, used and reused, aggregated or re-engineered to suit the purposes of multiple institutions, faculty members or instructional developers (Commonwealth of Learning, 2003).These courseware systems are at the core of online education. Producing such systems is expensive, but their value is maximized if they are designed to be flexible, customizable, interoperable, easy to update and reused. Online education should be more than simply the posting of educational information online. There is the provision via the Internet of fully realized courses with curriculum, bibliography, pedagogical sequence and so on. The large majority of online courses are developed in the fields of business management and ICT related areas. These are popular areas in traditional higher education, but additionally, they have proved good for online learning because they can be standardized and generally require less face-to face interaction or practice outside the computer. However, other subjects such as education and primary health care studies, which would normally require a strong face-to-face/practical experience, are also popular online courses. Suppliers of online education primarily focus on courses that can be easily produced and reproduced, but also on where there is a large demand.

Internet delivery is particularly popular with post-graduate courses, presumably because of their shorter duration and greater independence, as well as their popularity with full-time professionals. A survey of online education and services in Australia (Bell et al., 2002) shows that the courses most repeated are those leading to e-commerce and online education diplomas – that is, the object, as well as the means of study, is the Internet – and that 90 per cent of the online courses at universities are at post-graduate level.

Open content

The growth of the Internet has led to increased availability of content and, as with public libraries; there is a demand for knowledge to be shared and freely or cheaply accessible. A well-known initiative to make courses publicly available online is Open Courseware (OCW). Posting information online is not the same as providing an online course. In some cases, all that is posted on the OCW site is the syllabus and bibliography. Whether because of intellectual property rights restrictions or

management motivations, OCW does not offer access to lectures, explanations and discussions or to the key readings. For most users the OCW initiative is not sufficient, particularly for those in developing countries where access to reading material is limited. An additional obstacle is that all information is in English and OCW's plans are that it will continue this way (UNESCO, 2002). Higher education institutions from the developing countries are greatly interested in pursuing an open courseware initiative, but not at any price. They have cultural and language concerns as well as the more general infrastructure concern, and they recognize current intellectual property rights barriers. The interest lies not only in accessing information but also making accessible information from its own country and communities.

Currently, there are no informal knowledge sharing initiatives targeting the needs of developing nations, such as the international Open Knowledge Network consortium, but not at the specific level of higher education. Professionals from developed and developing countries have suggested (UNESCO, 2002) that open courseware, should:

- Provide educational resources for college and university faculties to adapt them in accordance with their curricular and pedagogical needs
- Include the technology to support open, meaningful access and use of courseware
- Include at a minimum the course description, syllabus, calendar and at least one of the following: lecture notes, demonstrations, simulations, illustrations or learning objects

Research and publication

The Internet is also having a major impact on research and publication. The Web has produced a huge increase in "grey literature" – online publication of research outside the traditional mechanisms of academic publishing. The opening up of knowledge through online databases and journals has had a transforming effect. However, access to a large number of established refereed journals and databases is still controlled through subscription, and the ownership of the intellectual property contained in journals is tightly controlled by publishers. Secondly, the Internet is challenging and transforming academic research and publishing by establishing new models of peer review and publishing which will influence the balance of power as regards to who owns intellectual assets. This shift has the potential to democratize not just access to knowledge but also ownership and control over how that knowledge is used, with clear benefits and advantages for institutions in developing countries. In some cases online content is developed by the provider, the teacher, or the university, while at other times external content is used, adapted or not.

Content management

Content is provided primarily through Learning Management Systems (LMS). The newer and more advanced version (Learning Content Management Systems) offers additional features that focus on content management and authoring. LMS integrates the management of content – online modules and communication tools – with student registration and administration procedures. They enable an institution to develop electronic learning materials, to offer these courses electronically, and then to use the same system to test and evaluate the students and to generate student databases in which individual results and progress can be charted (Paulsen, 2003). Universities use commercial and in-house learning management systems to manage their online programmes.

The LMS market will be expanding with new and updated products and a diversified language offer. The provision of more languages and features, together with increased standardization or open source systems development, will reduce institutions' incentive to develop their own software. However, economic rationale does not always play a part in opting for the in-house development of a system; rather, decisions are often driven by the bargaining power and interests of ICT departments. Evidence from a study of LMS systems in European institutions (Paulsen, 2003) suggests that IT sections of universities and other institutions attach great importance to developing their own platform and not buying programmes developed by others. For example, in the United States only 7.2 per cent of institutions have developed their own LMS (Hawkins et al., 2003).

Free and open-source software (FOSS)

FOSS is a software that has made its source code public, and allows users to modify the programme and thus customize and adapt it to particular needs. FOSS, already widely used for web server technology, has a more limited presence in desktop software.

However, in the field of education, it has the potential to become widely used in management systems and on desktops. Firstly, universities are at the centre of open software development, that is, there is a strong connection between users and developers, which facilitates the continuous updating and support that ICT software requires. Secondly, the positive externalities of education

provide a strong incentive for sharing and maximizing the use of existing technology and content. Thirdly, FOSS, at least until there is a full commitment to interoperability, can provide the necessary communication links between different IT platforms and tools. Finally, the education software sector is still in its infancy and neither the commercial nor the FOSS market has a monopoly; consequently, early developers have the opportunity to find a niche.

The legal framework

The legal framework affecting online higher education extends from specific regulations in the field of education, like recognition of titles, accreditation of educational institutions, curriculum design, teachers' qualifications etc. to broader legal issues, including intellectual property rights, commercial law, security and authentication, electronic payment systems, consumer protection, applicable law, and fiscal and customs regulations. Both sets of regulations shape the ability to buy, sell, develop and use online higher education. For example, in order to sell a degree online an institution needs to be accredited and, the degree needs to be recognized; students want to be protected against provision default and unauthorized use of their personal data, course developers want to control the use of their work and Governments want to control the quality of online educational programmes.

Of the various legal issues affecting online higher education of particular relevance for developing countries: accreditation and recognition, and intellectual property rights (IPRs). These issues are of special interest to developing countries since these are the countries that suffer most from lack of access to, and recognition of, their knowledge resources, and are the net importers of online higher education.

Accreditation and recognition

Accreditation is the currency of higher education. While learning for its own sake has cultural value and in some circumstances can be viewed as a leisure activity, in economic terms it is accredited and certified qualifications that count. Through appropriate quality assurance approaches and accreditation systems, Governments and accredited institutions ensure and promote quality in higher education, support the transferability of degrees across states, regions or nations and guarantee the authenticity of a degree. National quality assurance and accreditation systems vary from one country to another and in many developing countries are non-existent. The lack of trust in a national accreditation system seriously undermines its educational credibility both nationally and internationally.

As regards accreditation, online higher education is an issue in the key areas of quality, transferability, authenticity and branding. The growth of harder-to-regulate online higher education, as well as the increase in the number of higher education students, and the internationalization and privatization of education, provides challenges for national accreditation systems. Online education increases the number of programmes and individual modules, as well as the number of institutions offering educational services. This creates problems of evaluation, inspection and examination, and educational services providers may find it easier to circumvent local regulation by going online.

Quality assurance and accreditation systems tend to be weak in most developing countries, particularly in Africa and the Arab regions. However, in the light of increasing demand for and supply of higher education, accreditation systems are being revised in those regions. Countries such as Malaysia and South Africa are already working on updating their quality assurance and accreditation systems

Intellectual property rights (IPRs)

IPRs play a role in determining the ability to access, produce, copy and distribute content and specific expressions of knowledge. Having access to knowledge does not prevent others from benefiting from such knowledge. However, economic policy has long supported the need to grant temporary property rights to innovators so as to enable a return on their investments and thus encourage them to continue innovating, thereby contributing to a society in general. On the other hand, IPRs also act as a deterrent to innovation by limiting free access to knowledge and information.

The effects are notably greater for developing countries that lack resources to pay for access, and that are net importers of such goods and services. Since education is a (contested) public good, and is strongly based on knowledge, the application of IPRs to education is of particular importance. The arrival of the Internet has aggravated the conflict in several ways. The Internet is promoting more knowledge exchange around the world – from developed to developing countries, and vice versa. Since online education services derive from diverse sources (music, software, content, design, media, etc.), they are also restricted by varied protecting rights, which are now enforced by both technical and legal methods.

Moreover, free public access to knowledge (e.g. through libraries) is not guaranteed through the Internet.

Implications of the Internet for higher education

Although the future of new technological developments promises increased accessibility to information at a low cost, this access is not without its own pitfalls. From an economic point of view, some disadvantages include the selection of a costly technological solution when a simpler and existing technology might suffice. The most important consideration for the majority of developing countries is economic independence. It is in many of the economically developing countries that the largest distance learning projects are undertaken. A top educational priority for many such countries is to improve the cost effectiveness of education and to provide training and jobs for the general population. Researchers across the globe are calling for the establishment of national priorities for research in areas such as distance education (Jegede, 1993).

Research-based distance education programmes face a number of obstacles around the world. The lack of financial resources available for conducting adequate needs assessment in many countries, particularly prior to embarking on a massive distance education plan, is a common problem (Mc Isaac, 1990). In many cases, investing money in research is perceived to be unnecessary and a drain from areas in which the money is needed. Time is an additional problem, since programmes are often mandated with very little start-up time. In the interest of experience, an existing distance learning programme from another country may be used and revised, but many times this does not adequately answer the needs of the specific population.

One solution to the lack of adequate resources available locally has traditionally been the donation of time and expertise by international organizations to help in developing project goals and objectives. The criticism of this approach is that visiting experts seldom have adequate time to become completely familiar with the economic, social, and political factors influencing the success of the project. A second, and more appropriate solution, has been to train local experts to research, design, and implement sound distance learning programmes based on the needs of the particular economy. Distance education and its related delivery systems are often called upon to support national educational priorities and the current political system. One goal of education, particularly in developing countries, is to support the political organization of the country and to develop good citizens. Distance education programmes that endorse this priority will have a greater chance for success. National political philosophies and priorities are found reflected in the diversity of the distance education programme around the world. These programmes conform to prevailing political, social, and economic values.

In fact, it is likely that in online higher education both branding and accreditation will play an important role in shaping the market. But they must not be confused: branding provides the marketing value, while accreditation makes a course valid. Additionally, there is the question of the validity of an online course if the institution cannot be sure who actually took an online examination. As a result, ensuring the authenticity for e-learning courses may imply added costs, such as the establishment of centres for examination purposes, which may have an impact on financial sustainability. The submission of written assignments, as in offline education, also creates concerns over the authenticity of students' work. Institutions are exploring a combination of physical presence, technical tools and pedagogical measures to overcome authenticity issues. Currently, there is no single international accreditation body for either online or offline higher education.

Education has traditionally been in the national domain, and thus most regulations are at the national level. In order to be meaningful, global education requires transparent and recognizable standards of accreditation, but the debated search for an international accreditation system is in itself being questioned. Organizations from developed countries reject the idea of developing an international accreditation system on quality grounds and organizations in developing countries dislike supranational regulations that could limit a country's cultural identity and might fail to take into account the different levels of development. International measures to assure students of the value and transferability of their studies have developed primarily in a second area – one that is complementary to accreditation, namely recognition. Most of the initiatives to recognize titles granted by educational institutions in other countries are at a regional level. In certain professions, such as teaching, medicine, law and architecture, professional certification is essential in order to be able to work. This certification is greatly restricted on a geographical basis. Moreover, professional certifications usually have a strong face-to-face and practice component: for example, no one would want to be operated on by a surgeon with a purely online degree. Thus, it is not surprising for courses leading to the professional qualifications just mentioned to have a limited presence in the online sector.

In specific cases, online courses can lead to industry-standard certifications, which are very valuable in themselves. The reasons for its success are clear: it has access to a large amount of funding, has a standardized curriculum, and benefits from an excellent network infrastructure, as well as strong partnerships and marketing. In a world where access to and use and creation of knowledge is central to social and economic development, higher education is in increasing demand. Online higher education is in some cases providing further educational options for students, promoting the sharing of information and knowledge worldwide, reinforcing ICT use and access, and supplementing traditional modes of supply of education.

Constraints in developing online higher education

Current initiatives in the use of ICTs in education in developing countries are concentrated on the progressive use of ICTs in education (CD ROMs, e-mail communications, basic acquisition of ICT skills etc.) rather than on purely online higher education. Face-to-face delivery and traditional distance education continues to provide the bulk of education. The opportunities to develop online higher education include an expanding higher education population, a strong interest in developing ICT-based skills and education, and an interest in financing ICTs. Further opportunities are also available, in some cases because of the existing educational infrastructure, and the prospects and resources offered by other forerunners. On the other hand, institutions face a series of constraints in developing online higher education which includes the lack of access to ICT infrastructure, the high cost of ICTs, the lack of ICT skills, international competition and student preference for face-to-face teaching etc.

Lack of access to ICT infrastructure and applications

The lack of access to ICT infrastructure and applications is often highlighted as being of particular importance to developing countries. While this is true, there are some examples of innovative and appropriate methods of using technology. Similarly, there are open approaches (open software, open standards; open content and diversity) that can promote wider access to technology and content. Moreover, ICT capacity will continue to increase in developing countries, making the expansion of online education possible.

Economic drivers to invest in higher education

The economic drivers to invest in higher education consist of more than simply the desire to directly reduce the costs of education. The assumption that online education is cheaper than traditional education is questionable as cost-savings examples have not been properly verified. In each case, a review of the cost of online higher education in terms of affordability, profitability, efficiency and sustainability is necessary for understanding and evaluating the rationale and implications of investing in online higher education. The Internet is in some cases shifting the cost of online higher education from the Government to other providers (public–private partnerships), from the institution to the students (in the form of increased fees), from national to international providers (through sponsorships and partnership agreements) and from national to international students (by charging differential fees to non-domestic students). Thus, online higher education is being financed by a number of stakeholders with different interests, and although there is a momentum to invest in ICTs for online education, private investors are not always governed by educational priorities nor by the imperative to bridge the digital divide or to promote local content.

Efficiency to the educational sector

ICTs increase specialization, which in turn can bring more efficiency to the educational sector by enhancing internal organization, communication and knowledge sharing, and by allowing teachers to specialize in their field of expertise. Additionally, the Internet is encouraging new thinking about the validity of current business models for the provision of education and access to research.

Ownership of knowledge

The Internet has impacted on thinking about the purpose and profitability of academic research and publishing, as well as having forced consideration of the value of open systems in technology, thus prompting similar debates in higher education about the use of open content and open technology. The Internet has expanded the diffusion of knowledge but it has also altered the terms of ownership of knowledge, with pulls in different directions. On the other hand, the desire to control intellectual property leads to increased privatization of knowledge. Further clarification regarding the application of regulatory issues to online education, including intellectual property rights, is necessary in order to allow transparency and confidence. The Internet has also internationalized (the trade in) education, and is increasing access to international higher education services, both online and offline. These effects contrast with the fact that developing countries tend to be at a disadvantage in the international education arena, where institutions in developed countries attract most international students, and degrees

from developing countries are far from being fully recognized in developed nations. The Internet is promoting competition for international students and thus it increases pressure on developing countries' institutions. Additionally, online higher education requires further strengthening of quality assurance and recognition processes.

Recommendations for developing countries

On the basis of the above analysis a number of suggestions are provided below for Governments and educational institutions in developing countries to promote the online higher education. However, despite the growing competition that developing country institutions face in the provision of higher education from developed countries, they still have a broad range of strategies that they can use to attract students:

Firstly, they can differentiate their courses through local content/language. Secondly, they can gain recognition of their institutions and courses by attaining international accreditation either on their own terms or through association with a developed country or regional institution.

Thirdly, they can maximize the advantages of geographical presence in a market. And finally, they can pursue a strategy of developing regional leadership, although this is clearly not a strategy that all institutions can succeed in pursuing. One important role of Governments is to ensure that the current widespread enthusiasm for online education does not overshadow the wider objectives that they set for initiatives such as reaching students who are under-represented (owing to disability or geography, or for some other reason), providing local knowledge, and reducing the digital divide. Governments have the opportunity to pursue policies that redress existing online higher education deficiencies and that maximize educational and developmental outcomes.

Some of the options available to Governments to ensure that online higher education has a positive impact on reducing the digital and educational gap are:-

Creating awareness, encouraging collaboration and the dialogue between educational professionals, the IT sector and other stakeholders, such as students, who are multiple stakeholders with different interests in online higher education. A better understanding of each other's interests, aims and strengths facilitates the promotion, design and implementation of online educational initiatives.

Fostering a culture of learning, through investing in traditional resources (books, teachers) and technologies: funding online infrastructure and applications should not be at the expense of traditional knowledge resources, and local content and existing expertise are a valuable resource to be supported and promoted.

Promoting coherence between educational and ICT strategies: the use of the Internet in education has the potential to, among other things, provide wider access to knowledge, promote ICT skills and enhance educational networks as well as international presence. However, ICTs are only tools to achieve educational objectives. Relevant ministries within Governments need to consider broader educational strategies when thinking about e-learning so that e-learning strategies meet current and future national educational priorities. There should also be coherence with the general e-strategy, so that measures to solve common concerns regarding infrastructure, skills and the use of open systems are consistently reflected in both sets of strategies.

Supporting the use of open technology and open content in higher education: the use of free and open source software encourages the deepening of ICT skills and allows for local customization, and as with open standards, it promotes the interoperability of different e-learning tools. Open content is a valuable option for developing countries, both to access foreign content and to further disseminate local content. Governments play a role in promoting open initiatives, in particular in the field of higher education, by promoting their use in universities.

Providing incentives for investing in e-learning and online higher education so that educational goals are maximized – for example, regulating the provision of online higher education, and promoting long-term sustainable partnerships between different actors (e.g. a software company and a university) that set minimum quality and reach requirements. The aim should be to enable an educational environment that provides equitable access to education and that is aware of the limits of a competitive environment.

Developing transparent quality assurance, accreditation and recognition measures both nationally and globally, through consultation with key stakeholders, ongoing evaluation and consensus, so as to ensure that they cover the specific nature of online higher education and that they allow the achievement of particular educational goals.

Monitoring and measuring the economic, educational and social benefits and/or costs of e-learning in general, and online higher education in particular, as well as car-

rying independent and rigorous research into the uses of online learning, so as to be able to benchmark and evaluate the efficiency of e-learning initiatives and return on investment.

Conclusion

In developing countries Governments' actions can contribute to making online higher education a sound proposition by creating an educational and policy environment that enables the expansion of higher education to previously excluded students. Such actions also encourages relevant and appropriate learning content and processes, promotes innovation and investment in education, and recognizes students' needs and efforts. However, it is not possible to give a categorical answer to the question of whether online higher education is a sound proposition for developing countries. Because, whether or not online higher education is a sound option for developing countries depends on potential financial opportunities rather than on the overall capacity to meet specific educational and developmental goals. Hence the Government's best option is to analyze the benefits of online higher education from the overall development perspective, including national educational objectives, and the competitiveness and quality of the online education on offer, with a full analysis of the financial restraints and the opportunities offered by partnerships and open source-software/ content approaches.

It can be concluded that online higher education can fulfill some of the promises made on its behalf to the extent that the educational and policy environment enables the expansion of higher education to the students who were denied of such facilities under closed classroom methodology of learning tertiary educational necessities.

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Feature

Quality Index in Education

S.N. Chakrabartty & Rumki Gupta

This paper describes various methods of combining a finite number of quality parameters to a single index to reflect quality in education, and thus provides a solution to the much-needed problem of quantitative measurement of quality. Various methods of arriving at the single index have been described. The proposed Quality Index satisfies various desired properties. The properties of the Index have been discussed and empirical verification regarding computation of the Index has also been done.

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Education is one of the most crucial elements in empowering people with skills and knowledge and in giving them access to productive employment in the future. It is well known that the changing global scenario and resultant major changes have had implications in all sectors. The education sector is no exception. The need for improving the sagging bottom line and acceptance of challenges to increase quality cannot be over emphasized. Hence, our education system must endeavour to achieve excellence especially when competition is already being felt. The National Policy on Education of the Government of India, formulated in 1986 and updated in 1992 inter alia aiming at compulsory education for all children, has reiterated the need for substantial improvement in the quality of the education system. For effective funding of elementary education in India, the 2% education cess was introduced in 2004-2005, which was earmarked for Sarva Shiksha Abhiyan (SSA). SSA aims at 100% enrolment for children aged between 6 and 14. It also aims to bridge social, gender and regional gaps. In the context of education, development does not only mean progress but needs to ensure that nobody is left behind. In a nutshell, our education system needs to be:-

- Committed
- Competent
- Cost effective
- Customer/stake-holders oriented

and ensure quality in education. Hence, there exists a need to focus on quality in education and a need to measure the quality.

Major Concerns

The Education Commission, while describing the role of education in the social and economic transformation of India, has commented that, "The destiny of India is now being shaped in her classrooms". The planners have rightly recognized the need of improvement in educational

facilities both in terms of quantity as well as quality. However, the outcome, as on date does not appear to be very encouraging.

As per the Human Development Index (HDI) of UNDP (2003), India ranks 127 in 2002 with HDI value of 0.595 (adult literacy rate of ages 15 and above is 61.3% and the Education Index is 0.59). HDI value of the world in 2002 is 0.729. This means we are behind 126 countries of the world in terms of HDI value. A large number of Asian countries and other developing/rather poor countries of the world are ahead of us.

In terms of the Education Index of the UNDP, India's rank in 2002 is 146 (along with Nigeria) with a value of 0.59 against the world average of 0.76. The index for India, however, has improved to 0.61 in 2003. In terms of Gender-Related Development Index (GDI), India's rank is 103 out of 144 countries.

However, there are some positive indications:

- Rank of India in terms of HDI has improved from 139 in 1995 to 127 in 2003
- HDI value for India has increased steadily from 0.437 in 1990 to 0.595 in 2002, and further increased 0.602 in 2003
- India's adult literacy rate of ages 15 and above has increased from 49.3% in 1990 to 61% in 2003
- Public expenditure on education as percentage of the GDP has increased to 4.1% in 1999-2001. Similarly, public expenditure on education as a percentage of the total Government expenditure has also registered an increasing trend (12.7% in 1999-2001).

Improving trends at the National Level: (Illustrative)

- Sarva Shiksha Abhiyan Programme launched by the Govt. of India envisages achieving goal of universal elementary education by 2010. This has also resulted in the collection of massive data even at the level of the District Information System for Education (DISE). The data capture formats and definitions, and concepts used for data collection are available at http://www.dpepmis.org, which is being followed uniformly across the state.
- Enrolment of girls as a percentage to total enrolment in university education has improved for all major faculties viz. Arts, Science, Commerce, Education, Engineering & Technology, Medicine etc. Total enrolment in general education has also improved.
- Drop out rate at different stages of school education has tended to decline.
- Number of school leavers after completing classes VI, VIII & IX number, has declined.
- Number of educational institutes offering Engineering, Medical, Dental and General education, has increased.
- Public expenditure on education has registered increasing trends.

Past studies

Past empirical studies have come out with various observations. Empirical studies followed different sampling designs and achievement tests. Thus, findings were not strictly comparable. Moreover, most of the studies were cross-sectional and no temporal comparisons were made. However, major initiatives to achieve universal primary education course came in the form of District Primary Education Programme (DPEP) which has now emerged as a major vehicle for bringing about quantitative and qualitative changes in primary education. Here again no sampling design was adopted for schools under the project. *Sarva Shiksha Abhiyan* has taken a holistic and comprehensive approach to the issue of quality. Agarwal (2000) found that the achievement scores are significantly different for:

- English and Hindi medium schools in mathematics
- SC students and general students
- Mathematics and language
- Gap in cognitive ability between Class-I and Class-IV
- Different types of management (schools managed by Municipal Corporation had lowest mean score)

However, DPEP studies on Kerala suggest that the type of management of the school is not an influential factor in learning achievement.

Shukla (1994) observed a different pattern of education attainment in different studies. Pupil's achievement was found to be related to the education of the father and facility for learning and education environment at home. Kalpana (2004) has given a theoretical framework of TQM to evolve a generic model for primary school

education based on field level research. She has come out with research findings and policy implications. The empirical study of Sahney et. al. (2004) has identified various quality element/components of the foreign education system. The elements/components have been grouped under three factors/contracts viz. Management System, Technical System and Social System. Gupta (2006) found that gender difference was practically nil for students of Madhyamic Examination in West Bengal. She also found performance of general category students were better than the SC/ST students.

Smith (2002) dealt with Quality Assessment of quality learning considering assessment of three P's i.e. assessment of:

- Process (individual learning process)
- Progress (progress of individual learner)
- Product (learning product)

Education Index, a part of the human development index of the UNDP, forms an important step to come out with quantitative measure of progress in terms of an Education Index. The Education Index considers (i) adult literacy rate and (ii) combined primary, secondary and tertiary gross enrolment. If the Adult literacy Index is X and gross enrolment index is Y, then Education Index

$$EI = \frac{2}{3}X + \frac{1}{3}Y$$

The Education Index of the UNDP serves the purpose of macro-aspect of progress in the educational sector. However, the Index does not consider large number of relevant parameters pertaining to infrastructural/procedural/social/qualitative attainments etc. Chakbabartty (1981) and (2005) in a different context, suggested several methods of combining finite number of parameters to a single index.

Defining quality of education

The National Policy on education, 1986, which was revised in 1992, reiterated the urgency to address the quality concerned in school education on a priority basis. A large amount of literature is available for attempting to find the parameters of quality of education. However, there appears to be no consensus among educationalists regarding the parameters of the quality. An illustrative list of major prerequisites for the quality in education could be:

- Reforms in teachers' training (pre-service and in-service education)
- Improvement in facilities and infrastructure and support services in schools
- Teachers' motivation and innovation
- Curriculum and teaching aids
- Pupil evaluation (feedback and corrective measures)
- Change in the style of teaching to make it attractive to the students
- Satisfaction to the others stakeholders viz. Government, donor agencies and most importantly the parents of the children
- Minimising the gap between the plan and achievement of education
- Encouraging achievement of cognitive and non-cognitive competency of the students
- Introduction of participatory management in elementary education with community support
- More teacher–community participation for better functioning of school and development of school vision etc.
- Monitoring and supervision.

Accordingly, the following three stages are proposed:

Stage–I Identification of the parameters of quality in education (Brainstorming, Customer Voice Survey, Literature Survey etc may be resorted to)

Stage–II Measurement on each parameter (Questionnaire, tests, have been developed sparingly. One needs to take stock of the situation and initiate actions for satisfactory measurement of each parameter/facets of quality in education)

Stage–III Combining all the parameters into a single index to reflect quality of education

After deciding the best method of arriving at the Single Index, an appropriate mechanism needs to be developed regarding collections of data relating to selected parameters and necessary compilation and analysis including presentation/circulation of information to the concerned authorities for adopting corrective measures.

Focus

The present paper will discuss various methods per-

taining to the above said third stage only. It may be desirable to deal with all the stages in a parallel manner and concurrently to give serious attention to the problem of quality of education in India.

Formulation of Quality Index

Set up

We may assume availability of measurement on each of the n-chosen quality variable/indicator i.e. we have X_{1i}, X_{2i}, X_{3i} ..... X_{ni} where X_{ij} denotes value of the j-th individual in the i-th variable j = 1,2, ...K. We may also have another vector as a target vector depicting target value on each variable or indicator or the achievements in the previous year in terms of the chosen variables which will be denoted as $X_{10}, X_{20}, X_{30}, ...X_{no}$. Thus, the quality can be viewed as a vector valued variable.

$$\begin{bmatrix} X_{1i} \\ .. \\ .. \\ X_{ni} \end{bmatrix}^9$$

which is to be compared with the target vector

$$\begin{bmatrix} X_{10} \\ X_{20} \\ .. \\ .. \\ X_{ni} \end{bmatrix}^9$$

Assumptions made

- Measurements are available for each chosen quality variable/indicator
- Quality variables/indicators may:
  - have different units;
  - be independent or may have different degree of correlations
- Each X_i is positively related to the quality. In case, an usual quality indicator like dropout rate etc, where the lower value of the variable implies better quality, we will consider the reciprocal of that variable
- The target vector could be the targets/goals decided. Otherwise, last year's performance could be taken as the target vector. Availability of target vector is assumed.

Objectives

- We are looking for a function from R^n
- R to have a single measurement of quality
- Develop a method of obtaining Quality Index

Methods

Index Number Approach

Ratios

The ratio X_{ij}/X_{io} denotes achievement in respect of the i-th indicator/quality variable in comparison to the target. The ratio is free of unit.

Quality Q may be defined as

$$Q = \frac{1}{n}\sum \frac{X_{ij}}{X_{io}} \qquad ...(1.1)$$

or

$$Q = \sum \frac{W_i X_{ij}}{X_{io}} \qquad ...(1.2)$$

where $\sum W_i = 1$

Objective method to find weights

Weights could be found so that $\sum W_i = 1$ and Var (A) is minimum where A = W^1 DW and D is the Var-Cov. Matrix of the quality variables.

Define $L = W^1DW + \lambda (1 - W^1e)$

where e denotes the unit vector in R^n and λ is the Lagrangian multiplier.

Then $\frac{\partial L}{\partial W} = 2DW - \lambda e = 0$ and

$$\frac{\partial L}{\partial \lambda} = 1 - w^1 e = 0$$

Thus $W = \frac{D^{-1} e}{e^1 D^{-1} e}$ and $\lambda = \frac{2}{e^1 D^{-1} e}$

Quality found through the above has the following properties:-

- Q has minimum variance
- Co-variance between Q and Xi is constant
- All weights may not be non-negative. This is especially true when the indicators are highly correlated

- Non–negative weights can be ensured by adding another criterion viz. $w_i > 0$ in which cases, the problem boils down to a Quadetric Programming formulation

If it is found desirable to get weights such as X_i is proportional to Cov (Q, X_i) then it could be proved that W is the eigen vector corresponding to the maximum eigen value of the variance covariance matrix of the indicators.

If we want W_i as proportional to $\frac{CoV(Q, X_j)}{Var\ X_i}$, then

$W = \frac{S^{-1}U}{e^1 S^{-1}U}$ where S is the diagonal matrix of SD's of the qualit variables and U is the maximum eigen value of the correlation matrix

The above methods

- help to find weights in objective fashion
- cannot help to find variance – covariance matrix if financial indicators etc are also considered where we get only one value for a time period say one year

So far, additive models were discussed. We can have multiplicative models like $Q = \sum \frac{(X_{ij})^{wi}}{X_{io}}$

with $\sum W_i = 1$ and $Wi > O$

By taking log on both sides, we get

$Log\ Q = \sum W_i \log \frac{(X_{ij})}{X_{io}}$ which boils down to additive model

Geometric Approach

Here, instead of ratio of indicators, actual value of the vector X and the target vector T will be considered avoiding the estimate of weights. Quality can be viewed geometrically as follows for two variables space:

$$Q = \left[\left(\sum X_{ij} - X_{io}\right)^2\right]^{1/2} \quad ...(2.1)$$

Here, quality is defined as the distance between points X & T. The method is simple but has the following limitations:

N, M may get equal value of quality despite the fact that the position at M is clearly having more quality than N.

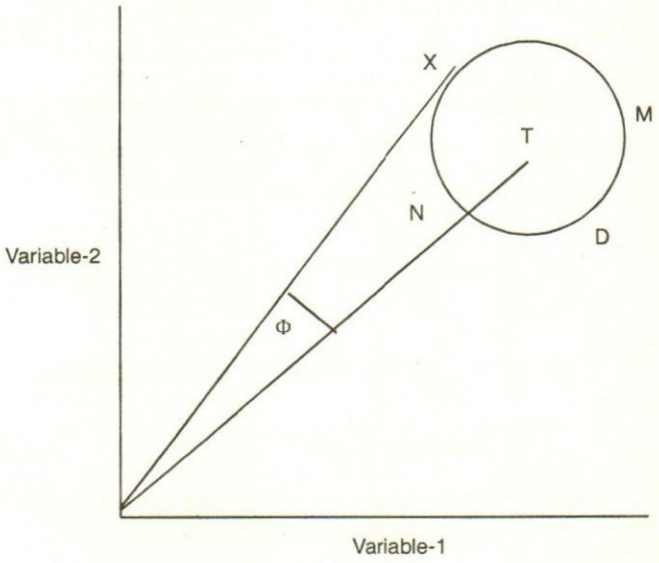

Fig. 1.

Better approach could be to define Q as

$$Q = \left|\frac{QX}{OT}\right| Cos\,\Phi \quad ...(2.2)$$

The above method considers the angle between the vector X & T in addition to the length of the indicators. A smaller angle would be desirable.

The above method can be easily generalised to n – dimensional space to measure quality involving n – number of variables/indicators.

Geometric mean/volume approach

Instead of arithmetic mean of the ratios, one can use geometric mean which could be better way of averaging when the indicators or quality variables reflect rates or are given in ratio/percentages.

$$Q = \left[\Pi\left(\frac{X_{ij}}{X_{io}}\right)\right]^{1/n} \quad ...(3.1)$$

Alternatively quality could be defined as:

Area of the rectangular for which OX is a diagonal in Fig. 1

$$Q = \frac{\text{Area of the rectangular for which OX is a diagonal in Fig. 1}}{\text{Area of rectangular for which OT is a diagonal in Fig. 1}}$$

Thus $$Q = \frac{\Pi X_{ij}}{\Pi X_{io}} \quad ...(3.2)$$

Square of the area of the parallelogram formed by the vector OX and OT in Fig. 1 is $\sqrt{n-1}|\Sigma|$ where Σ is the dispersion matrix. Then we can define:

$$Q = \frac{\sqrt{n-1}}{|\Sigma|} \text{ if } \Phi = 0°$$

$$= \frac{d}{|\Sigma|} \text{ if } \Phi = 0° \text{ where d is the distance}$$

between X and T ...(3.3)

Observe that quality as measured by 3.1 and 3.2 have one – one and onto correspondences.

Quality as an unobservable latent variable

Here, Quality is not observable but the weights can be found through Principal Components analysis of the standardised quality variables. The estimate of

$$E(Y/X_1X_2.....X_n) \text{ is } \frac{\lambda_1P_1 + \lambda_2P_2 + ...\lambda_vP_n}{\lambda_1 + \lambda_2 + ... + \lambda_v} \quad ...(4.1)$$

Where λ_1 is the first characteristic root of the correlation Matrix R. Other λ's are defined accordingly. N – principal components of the quality variables are:

$$P_1 = \bar{\alpha}_{11}\frac{(X_1 - \bar{X}_1)}{S_1} + ... + \bar{\alpha}_{1n}\frac{(X_n - \bar{X}_n)}{S_n} \quad ...(4.1)$$

where $\alpha_1 = (\alpha_{11}, \alpha_{12}.....\alpha_{1n})^1$ is the characteristic vector of R.

P_2.....P_n are similarly defined

Thus, the weights are derived from the data.

For the special case of n = 2, Nagar (2004) has given the asymptotic distribution of the estimate of Y and its mean and variance when number of observations tend to be large.

Comparison among the methods

Measurement of the quality is to find a function from R^n to R. Illustrative list of desired properties of the function are as follows:

(i) The function should be continuous. All the proposed methods satisfy the condition

(ii) The function should be monotonically increasing: All the methods satisfy the condition except 2.2 and the Principal Component method.

(iii) The function should be symmetric over its argument i.e. the function to be invariant of ordering of the indicators/quality variables. All the methods satisfy the condition

(iv) The function should satisfy time reversal test i.e. Q_{XT}. Q_{TX} = 1 where the target vectors are available. Methods proposed in 3.1 and 3.2 satisfy the condition. For the method 2.2, Q_{XT} . Q_{TX} tends to unity as theta tends to 0.

Findings

- Various methods of measuring quality as a function of chosen quality variables have been discussed. Attempt was also made to have a theoretical comparison among proposed methods. The geometric mean approach (or the formula 3.2) has all the desired properties and avoids calculations of variance – co-variable matrix or correlation matrix and hence may be accepted as the best method (among the methods discussed).

- The Geometric Mean approach could also be used to form an index by considering the target vector as last year's performance. If the last year is taken as the base year, one can find the index reflecting improvement of quality for each year with regard to the base year satisfying time reversal test and also enabling to form chain indices.

Empirical verification

Since the Geometric Mean method (3.1) which has one to one correspondence with (3.2), appears to be the best method with respect to the desired properties of function from R^n to R, empirical verification was carried out for these two methods only.

Data

The following 17 readily–available indicators pertaining to primary education in the state of West Bengal were considered for the years 2002–03, 2003–04 and 2004–05. Details are annexed.

Definitions

Definition of the chosen indicators are as follows:

1. % Single Classroom Schools $= \frac{\text{Primary schools having single classroom}}{\text{Total primary schools}} \times 100$

2. % Single teacher Schools $= \frac{\text{Primary schools with single teacher in position}}{\text{Total primary schools}} \times 100$

3. % Schools with SCR ≥ 60 $= \frac{\text{Primary schools having student classroom ration } \geq 60}{\text{Total primary schools}} \times 100$

4. % Schools with common Toilet $= \frac{\text{Primary schools having common toilet}}{\text{Total primary schools}} \times 100$

5. % Schools with girl's Toilet $= \frac{\text{Primary schools having girl's toilet}}{\text{Total primary schools}} \times 100$

6. % Enrolment in Government Schools $= \frac{\text{Enrolment in primary schools having Education Department, Local Body, Tribal Welfare Department \& others as school management}}{\text{Total enrolment in primary schools}}$

7. % Enrolment in Single teacher Schools $= \frac{\text{Enrolment in primary schools having single teacher}}{\text{Enrolment in total number of schools having primary category}} \times 100$

8. % No female Teacher schools (teacher $\geq$ 2) $= \frac{\text{Primary schools having teacher } \geq 2 \text{ but no female teacher}}{\text{Total primary schools}} \times 100$

9. % students in Schools without building $= \frac{\text{Enrolment in primary schools having no building}}{\text{Enrolment in primary schools}} \times 100$

10. % SC enrolment $= \frac{\text{Enrolment of SC in primary schools}}{\text{Total enrolment in primary schools}} \times 100$

11. % SC girls to SC enrolment $= \frac{\text{Enrolment of SC girls in primary schools}}{\text{SC enrolment in primary schools}} \times 100$

12. % ST enrolment $= \frac{\text{Enrolment of ST in primary schools}}{\text{Total enrolment in primary schools}} \times 100$

13. % ST girls to ST enrolment $= \frac{\text{Enrolment of ST girls in primary schools}}{\text{ST enrolment in primary schools}} \times 100$

14. Pupil teacher Ratio (PTR) $= \frac{\text{Total enrolment in schools of primary category}}{\text{Total teachers in primary schools category}} \times 100$

    (Para teachers have been included while calculating PTR)

15. Student classroom Ratio (SCR) $= \frac{\text{Total enrolment in primary schools}}{\text{Total classrooms in primary schools}} \times 100$

16. % of girls enrolment.

17. % female teacher $= \frac{\text{Total female teachers in primary schools}}{\text{Total teachers in primary schools}} \times 100$

    (Para teachers have been included while calculating this indicator)

Note:- For a few indicators, numerically lower values imply improvement viz. student – classroom ratio, percentage of school without building etc. Reciprocal of such variables were considered in the analysis to ensure positive relationship of each indicator with quality.

Analysis

Product of values of chosen 17 variables are:

2002 – 03 : 8, 702, 950.717

2003 – 04 : 19, 497, 156.11

2004 – 05 : 96, 995, 038.8

Thus, as per formula (3.2)

- Quality in 2003 – 04 with 2002 – 03 as base year was 2.2403
- Quality in 2004 – 05 with respect to the previous year was 4.9748.
- Quality in 2004 -05 with 2002 – 03 as the base year was 11.1451.

Numerical values of the Quality Index in primary education for West Bengal are given in the following table:

Table 1

	Quality	Index
Year	As per formula 3.1 i.e. Geometric Mean	As per formula 3.2 i.e. area of rectangle
2002 – 03 (Target factor or base year)	1.0	1.0
2003 – 04 With respect to base year	1.0486	2.2403
2004 – 05 With respect to the base year	1.1524	11.1451
2004 – 05 With respect to 2003 – 04	1.0990	4.9748

The following may be noted. Let Q_t / (t – 1) denotes quality in primary education for the year t with respect to the year (t – 1).

Here, as per formula (3.2)

$Q_{2003-04/2002-03} = 2.2403$

$Q_{2002-03/2003-04} = 0.4464$

So, $Q_{2003-04/2002-03} \times Q_{2002-03/2003-04} = 1$

Thus, the proposed Index for Quality satisfies Time Reversal Test.

Also,

$Q_{2004-05/2002-03} = 11.1451$ which is equal to

$Q_{2004-05/2003-04} \times Q_{2003-04/2002-03}$

i.e. 4.9748 x 2.2403

Thus, the proposed Index for Quality facilitates formation of chain indices.

Properties of the Index

- The two indices are

$$Q = \left(\Pi \frac{X_{ij}}{X_{io}} \right)^{\frac{1}{n}} \quad ...(3.1)$$

and

$$Q = \frac{\Pi X_{ij}}{\Pi X_{io}} \quad ...(3.2)$$

- The two indices have one to one and onto correspondence. For simplicity in calculation, the index at (3.2) may be considered.
- The Index (at 3.2) has following properties:
  - it is simple
  - can consider all indicators
  - avoids calculations of var – cov matrix or correlation matrix
  - avoids calculation of weights
  - represents a continuous function which is also monotonically increasing
  - it is symmetric over its arguments i.e. independent of order in which parameters have been recorded
  - Satisfies Time – Reversal Test
  - Facilitates formation of chain indices
  - Statistical Test of significance is possible (Ho: $p_1 = p_2$) since the index is essentially a proportion only.
- To have parity to general convention of Index value = 100 in the base year, the index can be multiplied by 100 to reflect readily percentage changes.
- The index depicts overall improvement/decline in the current year with respect to the base year taking all the parameters into consideration.
- The index can also reflect how far we are from the goals/targets/Millennium Educational Goal (MEG) by replacing X_{0i} with the millennium goal/target for the i-th parameter. This does not involve additional assumptions regarding the path of progress from the start to millennium goal.
- The index could best be applied to compare a particular geographical region say a State or a Country provided information to all chosen indicators are available for that region for all the time periods.

Sl. No.	Indicator	Year 2002-03	2003-04	2004-05
1	Student class room ratio (Reciprocal)	0.0164	0.0161	0.0175
2	Pupil Teacher ratio (Reciprocal)	0.0188	0.0192	33
3	% school with SCR>=60 (Reciprocal)	0.0235	0.0251	0.0255
4	% single class room schools (Reciprocal)	0.0429	0.0478	0.049
5	% Single teacher School (Reciprocal)	0.1234	0.1205	0.1639
6	% enrolment in single teacher's room (Reciprocal)	0.2174	0.2326	0.2857
7	% students in schools without building	1.1111	1.25	1.6666
8	% ST Enrolment	6.5	6.8	7
9	% school with girls toilet	8	10.6	16.1
10	% Female Teachers	24	24.3	25
11	% SC enrolment	29.1	28.4	28.5
12	% School with common toilet	43.9	50	58
13	% ST Girls to ST enrolment	47.7	48.2	48.7
14	% of girls enrolment	48.4	49.5	49.6
15	% of SC girls to SC enrolment	49.1	49.2	49.3
16	% no female teacher's school (Teacher> = 2)	52.5	51.6	51.5
17	% enrolment in Govt. school	99	99.6	99.5

Source: Ministry of HRD, GOI, www.dpepmis.org.

- If a national target emerge for each indicator, the index can facilitate reflecting improvements
  - at the national level
  - at each State/District level with regard to the given target
- The index assumes positive value for each indicator for all periods. If a particular indicator or parameter attains zero value in a time – period, the index will fail.
- Introduction of new indicator may require estimation of value of that indicator in base period also.
- The index may also be used to find sectoral or aspectwise indices viz separate index for
  - School infrastructure
  - School performance
  - Others

And combine these aspectwise indices through properly designing weighing diagrams/procedures.

- The index does not consider interrelationships among the parameters. A study can be undertaken to find correlations among various pair of parameters. If for a particular pair, correlations is high then appropriate methods to deal with multicolinearity may be adopted. Alternatively, a factor analysis approach may be explored to find independent factors.
- The index does not throw light on relative contribution of each parameter to overall value of the index. Stepwise Regression Analysis or Multiple Regression Analysis after normalising the independent variables may be undertaken in this context.
- If R^2 happens to be small, we may consider suitable transformations (non-linear) of the independent variables so that the R^2 for the transform variables are high.
- The above method of finding index for quality of education can contribute significantly to identify plans and associated action based on the observed value of the index. In addition, the index can also help to develop action plan in a micro sense for the few parameters where there were decline or marginal improvement/progress.

Desired actions

- Identify the parameters of quality in education through brain storming, customer voice survey, literature survey etc and develop questionnaire/ tests/tools for measurement of each such component.
- To develop, modify and standardise appropriate tests/tools for evaluation of cognitive and non-cognitive abilities of the pupil for all classes in the school. Beside comparison, the tests may also throw light on pattern of growth of abilities in pupils.
- Develop appropriate training modules for school teachers and support staff
- Increase awareness of quality to all concerns
- Find short-term and long-term targets for each such chosen variable
- Find distribution of the Quality Index measuring overall quality in education
- Have appropriate policies regarding effective monitoring and supervision, and data collection
- Formulation of Resource Groups at the sub-district, district, state and national level to facilitate quality improvement in school education.

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Indicators of Primary Education West Bengal

□

The most important part of being a great coach is having great players.

– Geno Auriemma

Feature

Growth and Structure of the Indian Textile Industry

I.R.S. Sarma & V.K. Reddy

The textile industry occupies a unique place in the Indian economy. This paper presents the growth rates of different variables and their ratios for textiles and industries associated with textile products. The growth rates have been calculated on an all-India basis and across 14 major states from 1979 to 1980 and 2000 to 2001. For most of the states, the results reveal that all variables and ratios explain the increasing capital intensity, falling employment, rising labour productivity and falling labour costs for both the industries.

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The textile industry occupies a unique place in the Indian economy and has been contributing to 14 per cent of the total industrial production. The industry contributes to nearly 30 per cent of the total exports and is the second largest employment generator after agriculture.

As WTO countries phase out their import quotas on textiles and apparel by January 1, 2005, the Indian textile industry will face increasingly intense competition in markets both at home and abroad, especially from other exporting developing countries. To meet the competitive challenges faced in a liberalized trade environment, the industry should identify growth areas to improve production and productivity levels. In light of this observation, the present study attempts to analyze the growth and structure of textiles and textile product industries during the eighties and nineties.

In this paper an attempt has been made to analyze the growth and structure of the textiles and textile products industries for all of India and 14 major states, as has been observed for periods during pre-liberalization (1979-1980 to 1990-1991), post-liberalization (1991-1992 to 2000-2001) and the overall period of the study (1979-1980 to 2000-2001). To analyze growth and structure, compound growth rates have been calculated by using exponential functional form $Y = a.b^t$ for the variables and their ratios which are under study.

The growth pattern observed by the variables provides an indication of efficiency of factors of production and technology undercurrents. These variables are NOF: Number of Factories, OUT: Output, CAP: Capital, EMP: Number of Employees, ENE: Energy, MAT: Materials consumed, EML: Emoluments, GVA: Gross Value-added (see appendix).

Growth Pattern of Variables in Textile Industry

The compound growth rates for the variables under

Table 1: Annual Compound Growth Rates of Number of Factories and Output for Indian Textile Industry

	Textiles			Textiles products		
	Pre Lib	Post Lib	Overall	Pre Lib	Post Lib	Overall
Number of Factories (NOF)						
India	-0.3934#	–4.0311	–0.0412	16.651	1.8696	3.8482
Andhra Pradesh	4.8456	–14.8654	–0.171	0.3781#	8.8651	4.4061
Bihar	–11.3112	–3.4786#	–6.8415	–3.514#	–4.227	0.6467#
Gujarat	–2.9652	0.9696#	–0.1204	–1.4753#	3.9723	17.165
Haryana	–2.1839	0.7246#	1.0237	4.6202	5.5865#	9.7745
Karnataka	–3.475	–11.7384	–16.564	1.0261	18.7561	10.5412
Kerala	0.9215#	5.9544	4.0668	–7.185	15.678	–1.93#
Madhya Pradesh	–2.2517	–11.445	–2.991	0.9326#	2.494#	0.7796#
Maharastra	–1.1517	–4.2594	–1.6522	–0.3398#	0.6294#	2.4837
Orissa	0.334#	–4.9456	–0.1096#	–0.8193	8.6375	6.1275
Punjab	–3.4222	–5.3047	–2.641	4.3173	1.394	4.2402
Rajastan	2.8892	–5.1518	3.3314	3.2121	7.5652	6.5226
Tamil Nadu	3.6942	1.4833#	4.5098	4.4475	8.3694	8.0215
Uttar Pradesh	20.033	0.8491#	0.849	11.3568	6.9496	9.6456
West Bengal	–5.0113	–1.628	–2.789	–2.8505	1.1614#	–1.3601
Value of Output (VO)						
India	8.702006	6.9342	8.8486	13.3319	14.1356	19.09
Andhra Pradesh	11.7011	0.3729#	9.6141	16.7053	26.0176	23.0937
Bihar	4.2049#	–3.4786	1.0633	15.8908	18.883#	11.373
Gujarat	6.1376	10.2568	7.0687	15.0096	11.1661	15.9311
Haryana	8.278	–3.2015#	8.1424	9.5183	22.168	23.9905
Karnataka	8.0689	1.9533#	8.5848	20.3811	26.9148	29.735
Kerala	7.7671	8.1799	10.0791	–0.1734#	17.7733	2.8903#
Madhya Pradesh	10.5576	9.7298	11.2452	3.5317	32.3514	16.6099
Maharashtra	6.1334	6.413	6.3244	11.2961	5.1965#	14.781
Orissa	13.9563	–14.6982	3.0738#	8.6715	29.4034	25.205
Punjab	13.3182	5.4631	10.557	12.5474	11.8981	14.6476
Rajastan	13.7555	3.415	11.6848	12.7491	18.8223	21.3077
Tamil Nadu	12.04	8.3439	11.9691	18.6258	19.0688	24.7278
Uttar Pradesh	8.9071	0.3919#	6.7886	12.1058	17.2613	19.1399
West Bengal	3.416	6.9345	4.859	6.8535	9.055	11.8774

"#" Denotes Insignificant

the study have been presented in Tables 1 to 4. The annual average growth rates are almost significant for textiles and textiles product industries for all India. From table 1 it is evident that the variable Number of Factories (NOF) has a negative growth rate for all-India textiles, whereas there has been a positive growth for textile products during all the periods. The growth rates of value of output (VO) for textiles products are higher than for textiles for all-India during the study period. The output growth for textiles has decreased during the post-liberalization period, whereas in textile products an increased growth rate has been observed during the post-liberalization period.

The employment growth is usually a matter of interest second only to output. From table 2, it is observed that the employment (EMP) growth for textiles is negative during the post-liberalization period and overall periods, whereas there is a positive growth rate for textile products. In the case of different states the employment growth for

Table 2: Annual Compound Growth Rates of Number of Employees and Emoluments for Indian Textile Industry

	Textiles			Textiles products		
	Pre Lib	Post Lib	Overall	Pre Lib	Post Lib	Overall
Number of Employees (EMP)						
India	2.051445	–1.8038	–1.3181	4.593	10.4748	8.599
Andhra Pradesh	0.3186	1.753	1.1539#	9.23	17.3648	12.9945
Bihar	–3.35	0.694#	–2.659	–0.844#	–9.599	–0.8995#
Gujarat	–4.7404	0.91	–2.3494	7.9748	1.7576#	3.9945
Haryana	–2.2269	–0.3715#	1.0597	1.2076#	22.0349	12.3147
Karnataka	–3.0852	–0.6728#	–15.491	9.4791	11.7328	15.284
Kerala	–0.6126	5.2801	1.9009	–3.2365	8.2794	–2.72
Madhya Pradesh	–1.948	3.572	–0.41#	–7.8027	2.6997#	0.3526#
Maharashtra	–3.6524	0.5941#	–1.8915	–1.3578#	3.4761	2.7515
Orissa	5.3848	–1.6454	2.3578	0.6293#	17.9073	12.1999
Punjab	3.2967	–11.3546#	1.2732	10.5054	2.4941	6.6911
Rajastan	2.6696	3.2377	3.6228	1.854#	11.8625	5.0455
Tamil Nadu	1.2382	3.2039	2.4858	9.3154	11.4901	11.4013
Uttar Pradesh	–3.4787#	–0.2867#	–1.5644#	5.2781	6.3475	7.3996
West Bengal	–4.0352	16.163	–1.5725	–4.4407	–3.6977#	–1.906
Total Emoluments (EML)						
India	0.5220064#	0.4475	0.4425	8.962	12.9596	10.30141
Andhra Pradesh	3.0012	2.9941#	0.822	14.7558	21.0781	17.8578
Bihar	2.3127#	–3.1728	–1.891	3.823#	–13.5078#	–0.7852#
Gujarat	–2.163	–3.242	–2.7873	13.2648	1.0587#	7.5375
Haryana	0.5048#	–4.7197#	1.3305#	4.1918#	21.1156	14.3913
Karnataka	–0.4462#	–0.2666#	–0.0479#	11.8263	9.8151	16.3359
Kerala	0.7431#	5.506	2.8756	–0.989#	11.3954	–6.3411
Madhya Pradesh	0.643	–0.0633	–0.5091#	–4.8488#	11.9384	4.2158
Maharastra	–0.1401#	–3.3118	–1.2764	2.7582	–0.2876#	3.839
Orissa	5.6614	–6.6734	1.2664#	–2.2312#	21.8679	13.1736
Punjab	6.6528	–0.8696#	3.7029	15.4883	–1.0949#	8.001
Rajastan	5.297	0.885#	4.7972	3.7249	16.6125	9.0884
Tamil Nadu	3.6236	–7.9302#	0.4229#	11.7883	1.06#	11.7265
Uttar Pradesh	–1.2188#	–3.3851	–1.6136	5.7599	6.951	8.2133
West Bengal	–0.8433#	0.8012#	–0.094#	–0.2177#	–5.7028	0.2338#

"#" Denotes Insignificant

the textile industry is negative and insignificant for most of the states in both the pre and post-liberalization periods, whereas it is positive in the case of textile products for most of the states during the post-liberalization period as well as during the overall period of study.

The acceleration of employment growth is less pronounced than that of output growth for both industries. The policy implication of this observation would be that any attempt in increasing the employment should focus more on the sub-sectors of textiles. Moreover, significantly negative time-specific effects during the 1990s indicate that deregulation and trade liberalization have had negative effects on employment in the textile industry. Because of increasing competition with liberalization and globalization policies, there is a need for the industry to improve efficiency. Thus there is a fear that the liberalized regime in the Indian context may lead to unemployment which would be highly detrimental.

The examination of the growth trend in fixed capital (table 3) shows that positive and significant changes have taken place for all-India and for all the states for both the industries during all the periods. The growth in fixed capital

Table 3: Annual Compound Growth Rates of Fixed Capital and Material Input for Indian Textile Industry

	Textiles			Textiles products		
	Pre Lib	Post Lib	Overall	Pre Lib	Post Lib	Overall
Fixed Capital (FC)						
India	24.38754	13.2659	17.9568	30.838	20.3712	24.9299
Andhra Pradesh	29.1081	13.359	19.9428	48.8644	20.9266	30.4643
Bihar	14.383	3.6884#	7.8978	31.674	9.192	19.7621
Gujarat	21.6173	14.5589	15.8996	26.3815	18.2812	20.9841
Haryana	23.186	10.0677	17.0833	28.9453	29.1646	29.2429
Karnataka	26.8571	13.0872	17.0155	37.1634	29.8768	34.8832
Kerala	19.0789	12.7752	15.8407	20.8353	19.5327	15.139
Madhya Pradesh	24.94115	17.3895	20.7432	24.2219	23.5537	22.9672
Maharashtra	22.0364	13.0482	16.628	28.291	15.375	21.1791
Orissa	29.6572	2.4817#	14.8027	11.1416	39.6553	26.3934
Punjab	34.1614	13.6123	22.3794	30.7975	15.1439	21.6396
Rajastan	27.4326	9.6624	19.8289	32.7659	24.9086	25.9038
Tamil Nadu	25.4305	13.5436	19.0819	30.97	24.749	28.7602
Uttar Pradesh	27.6975	9.0979	19.0224	31.7987	16.9898	23.6937
West Bengal	22.8602	11.4846	15.7248	24.8393	6.5041#	18.6689
Material Input (MAT)						
India	5.852607	3.5353	5.6526	16.65	9.9872	10.891
Andhra Pradesh	9.099	–4.5765	6.226	11.6925	19.1933	14.044
Bihar	0.3179#	–7.0214	–2.813	11.5519	2.671#	4.481
Gujarat	3.7002	6.9333	4.0782	11.2147	7.1402	7.8204
Haryana	5.5095	–7.7844	4.526	6.7594#	18.7067	16.8215
Karnataka	4.3355	–3.2275#	4.6175	17.2872	23.478	22.308
Kerala	4.5298	4.205#	6.7802	–4.6471	12.3233	–4.586
Madhya Pradesh	7.779	6.5292	7.9056	1.9725#	22.8097	8.0643
Maharashtra	4.3832	3.8806	3.5299	7.7198	0.2452#	5.8496
Orissa	11.078	–18.2422	–0.2832#	5.2909#	29.4704	19.2609
Punjab	9.8868	–7.8143#	3.7507#	10.6522	–0.321#	4.5355
Rajastan	10.4436	–0.1536#	8.0306	8.3557	13.7062	12.6623
Tamil Nadu	8.0913	5.0904	6.528	13.7176	14.0383	16.0834
Uttar Pradesh	5.6314	–2.585#	3.581	9.4546	12.6397	12.2149
West Bengal	0.5599#	3.3404	1.1232	4.2106#	3.9982#	4.4615

"#" Denotes Insignificant

has been low during the post-liberalization period when compared to the pre-liberalization period in both industries across the states and for all-India.

The cost of production consists of raw material and stores, wages and salaries, other operating cost and power and fuel cost. Growth in materials consumed (table 3) has been less during post-liberalization compared to pre-liberalization for both the industries and shows better growth trend in the case of textile products compared to textiles during the overall period of study. The growth rate of energy (table 4) has slightly declined during the post-liberalization period compared to pre-liberalization for all the states, and almost the same in the case for all-India textile products. The growth rates of energy and materials consumed are smaller when compared to Fixed Capital input growth.

Structural Ratio of the Indian Textile Industry

In order to analyze the textile industrial production, it is worthwhile to examine some key ratios. Instead of just analyzing the ratios, it is more appropriate to analyze the changes in these ratios which will reflect the structural changes in the Indian textile industry at the aggregate and the state level. This has been done by formulating

Table 4: Annual Compound Growth Rates of Energy Input and Gross Value-added for Indian Textile Industry

	Textiles			Textiles products		
	Pre Lib	Post Lib	Overall	Pre Lib	Post Lib	Overall
Energy Input (ENE)						
India	6.064775	6.1491	5.8783	10.824	16.877	13.424
Andhra Pradesh	9.271	5.8301	8.9973	16.3436	32.014	21.7925
Bihar	3.9893#	1.2632	–1.0944#	0.4482#	5.9601#	2.8826
Gujarat	3.6049	7.2924	3.4582	15.0172	12.7887	13.2704
Haryana	7.0851	1.2377#	6.7416	4.7047#	23.2492	14.792
Karnataka	5.5206	0.5358#	5.2003	12.3083	30.3926	21.5684
Kerala	2.9376#	12.4235	6.1134	2.9176#	3.11585	–5.672#
Madhya Pradesh	7.491	5.7167	7.6149	2.5426#	16.5676	11.0973
Maharashtra	4.2851	2.5813	3.5351	7.5069	8.3373	8.2976
Orissa	15.4515	–9.4847	3.8997	17.3828	22.3938	19.6117
Punjab	12.8534	11.3748	11.1239	16.9314	16.5949	15.1147
Rajastan	11.4787	4.0935	9.901	6.9764	21.3429	15.6725
Tamil Nadu	10.8353	9.3675	9.9099	14.8459	21.1175	19.7446
Uttar Pradesh	6.6324	–0.7532#	3.6977	13.5452	12.9522	13.2755
West Bengal	2.5784	4.9831	2.7469	4.9149	0.453#	3.904
Gross Value-added (GVA)						
India	7.381279	5.441	7.245	16.2515	12.9396	21.2345
Andhra Pradesh	10.5702	–22.796#	30.289	21.9893	27.1567	26.3813
Bihar	2.2347#	–8.0126#	–0.1233#	17.7085	9.6213#	12.9555
Gujarat	4.1816	8.834	–4.9243	19.4604	7.8665	17.1925
Haryana	6.9829	–2.2363#	6.6958	13.2453	17.4609	23.61
Karnataka	7.6801	6.2953#	9.0207	20.6043	26.2429	30.8178
Kerala	7.4489	9.6898	8.8118	2.2605#	18.267	1.6899#
Madhya Pradesh	13.74	10.4744	10.434	–2.1103#	37.3551	16.2136
Maharashtra	5.9259	2.7262#	4.6798	14.2154	0.983#	16.9099
Orissa	13.8847	–17.1275	0.9128#	6.7561#	22.6336	22.282
Punjab	15.0966	10.045#	12.4865	18.1275	17.9657	19.443
Rajastan	12.2087	0.4177#	9.9387	14.5515	20.1142	23.6824
Tamil Nadu	12.1698	4.9311	10.1934	23.1253	17.263	27.205
Uttar Pradesh	6.8697	–0.8209	4.864	13.2373	16.8143	20.0104
West Bengal	2.1156#	7.5316	4.789	4.9836#	5.6559#	10.4582

"#" Denotes Insignificant

some specific equations to which these ratios would provide the answers. They are as follows:

- The cost of creating one job, i.e. growth of FC-EMP
- The growth in the productivity of an employee and per unit of fixed capital, i.e. growth VA-EMP and VA-FC
- The average wage of an employee, i.e. growth of EML-EMP
- Change in the share of wages in the value-added i.e. growth of EML-VA
- Fixed capital per unit of output i.e. growth of FC-VO
- Average output of an employee, VO- EMP
- Increase in labour cost per unit of output, i.e. growth of EML-VO
- Change in value-added generated by the one unit of output i.e. growth of VA-VO

The annual compound growth rates have been computed for these ratios for all the periods under study. These values are reported in tables 5 to 9. To gain insights into

Table 5: Annual Compound Growth Rates of Output per Employee and Gross Value-added per Employee for Indian Textile Industry

	Textiles			Textiles products		
	Pre Lib	Post Lib	Overall	Pre Lib	Post Lib	Overall
Output per Employee (VO/EMP)						
India	10.76207	8.6675	10.1526	17.304	3.6632	10.4925
Andhra Pradesh	11.4024	–1.3778#	8.4595	–74.612#	8.6271	10.0911
Bihar	7.5421	–4.193#	3.6999	16.7192	11.5017	12.2631
Gujarat	10.9023	9.3585	9.4206	6.9865	9.3902	11.9138
Haryana	10.5285	–2.772#	7.0845	8.3434	0.1523#	11.6863
Karnataka	11.1795	2.5616#	10.1402	10.9368	15.1835	14.466
Kerala	8.399	2.8979#	8.196	3.0047	9.4111#	5.6004
Madhya Pradesh	12.511	6.1461	11.6665	11.3892	29.6153	16.252
Maharashtra	9.8031	5.743	8.228	12.7024	1.7254#	12.0456
Orissa	8.5934	–13.0657	0.7169#	8.0489	11.5308	12.7195
Punjab	10.0644	5.8372	9.2927	2.0137#	9.392	7.94
Rajastan	11.1045	0.1712#	8.0642	10.898	6.9938#	16.2505
Tamil Nadu	10.7673	5.1199	9.4758	9.336	7.5794	13.3314
Uttar Pradesh	12.4431	0.6981#	8.3645	6.886	10.8963	11.7548
West Bengal	7.4317	5.3122	6.452	11.2969	12.792	13.7882
Gross Value-added per Employee (GVA/EMP)						
India	9.471786	7.1885	8.5544	11.64	24.662	12.6353
Andhra Pradesh	10.2551	0.5299#	6.8696	12.7271	9.7675	13.3734
Bihar	5.5934#	–8.727	2.5171#	18.5942	19.229#	13.8657
Gujarat	8.9738	7.9238	7.2825	11.4666	6.0949	13.1866
Haryana	9.2127	–1.8532#	5.6537	12.0489	–4.5544#	11.2974
Karnataka	10.795	6.8743#	10.5825	11.1849	14.5123	15.5578
Kerala	8.0986	4.3933#	6.9293	5.4234	9.906#	4.4004
Madhya Pradesh	9.3077	6.9011	10.8574	5.7323#	34.6262	15.846
Maharashtra	9.5672	2.0369#	6.5798	15.6117	–2.4845#	14.1747
Orissa	8.5102	–15.5114	–1.4457#	6.1405#	4.7249#	9.3682
Punjab	11.8062	10.3937#	11.2077	7.5711	15.4493	12.7275
Rajastan	9.5526	–2.8214#	6.3186	12.6772	8.2873	18.6113
Tamil Nadu	10.9192	1.6972#	7.7062	13.8053	5.7702#	15.799
Uttar Pradesh	10.3935	–0.4918	6.4222	7.9897	10.4514	12.6071
West Bengal	6.1568	5.9028	6.386	9.4448#	9.3856#	12.378

"#" Denotes Insignificant

the trends in the factor proportions in the textile industry, the industry can be set to capital-intensive or labour-intensive industry according to whether capital per employee (capital/no. of employees) is above or below the average for all the industries.

The concepts of capital-intensive and labour-intensive are used only in a relative sense and not in absolute terms. In this study both industries are observed to be capital-intensive for all-India and across the states. The growth rate of FC-EMP (table 8) declined during post-liberalization when compared to the pre-liberalization period. In other words a slightly increased labour-intensive character has been observed during the post-liberalization period compared to the pre-liberalization period for both the industries. But the employment growth is not significant during the post-liberalization period, indicating the fact that the fixed capital is growing faster than labour growth.

The growth of labour productivity (VO-EMP from table 5) is low for textiles during the post-liberalization period compared to the pre-liberalization period for all states and for all India, whereas it is reverse in nature and has

Table 6: Annual Compound Growth Rates of Output per unit of Fixed Capital and Gross Value-added per unit of Fixed Capital for Indian Textile Industry

	Textiles			Textiles products		
	Pre Lib	Post Lib	Overall	Pre Lib	Post Lib	Overall
Output per unit of Fixed Capital (VO/FC)						
India	–15.7553	–6.3301	–9.1224	–7.4952	–6.2235	–5.8372
Andhra Pradesh	–17.3918	–13.0075	–10.3232	–3.21139	5.0772#	–7.3481
Bihar	–10.184	–7.1792	–6.84	–15.788	–7.35#	–8.415
Gujarat	–15.8062	–4.286	–8.8412	–11.456	–7.1325	–5.082
Haryana	–14.8645	–13.2679	–8.9329	–19.4607	–6.989#	–5.2641
Karnataka	–18.8566	–11.1169	–8.4499	–16.8052	–2.9396	–5.1532
Kerala	–11.3945	–4.5705	–5.7843	–21.0239	–1.78	–12.2644
Madhya Pradesh	–14.3374	–7.6782	–9.4884	–20.7024	8.7853#	–6.361
Maharashtra	–15.9172	–6.6174	–10.3136	–16.9631	–10.1947	–6.393
Orissa	–15.6995	–17.1815	–11.7321	–2.4671#	–10.4131#	–1.2286#
Punjab	–20.7201	–8.0914	–11.7733	–18.256	–3.2363#	–6.9912
Rajastan	–13.5918	–6.2514	–8.1248	–20.0232	–6.104#	–4.608#
Tamil Nadu	–13.375	–5.195	–7.1056	–12.345	–5.6716	–4.0312
Uttar Pradesh	–18.7523	–8.7138	–12.2142	–19.6642	0.265#	–4.539
West Bengal	–19.4994	–4.5235	–10.8753	–17.9343	2.5558	–6.7728
Gross Value-added per unit of Fixed Capital (GVA/FC)						
India	–1.70497	–7.8041	–10.72	14.599	–7.4429	3.6974
Andhra Pradesh	–18.5392	11.0954	–11.9117	–2.68243	6.2009#	–4.0716
Bihar	–12.1294#	–1.17111	–8.0202#	–13.9386#	0.4251#	–6.806
Gujarat	–17.7313	–5.7677	–10.9872	–6.966	–10.4256	–3.8072
Haryana	–16.1697	–12.3541	–10.367	–15.7522	–11.6985	–5.6511
Karnataka	–19.2352	–6.8013	–8.0052	–16.5617	–3.6434#	–4.0754
Kerala	–11.693	–3.076#	–7.0489	–18.6046	–1.2816#	–13.4593
Madhya Pradesh	–17.5443	–6.9037	–10.293	–26.3436	13.772#	–6.765
Maharashtra	–16.154	–10.358	–11.9721	–14.0619	–14.3871	–4.2595
Orissa	–15.7883	–19.6073	–13.8911	–4.3837#	–17.1894#	–4.1608#
Punjab	–18.9729	3.5804#	–9.8589	–12.6994	2.8164#	–2.2039#
Rajastan	–15.1454	–9.2473	–9.8631	–18.2358	–4.784#	–2.2379
Tamil Nadu	–13.2133	–8.6059	–8.8734	–7.8647	–7.4863	–1.5652#
Uttar Pradesh	–20.8047	–9.073	–14.1626	–18.572	–0.1792#	–3.6863
West Bengal	–20.7857	–3.9168	–10.9402	–19.7987	–0.8878#	–8.1925

"#" Denotes Insignificant

increased slightly during the post-liberalization period in the case of textile products. This rise may be because of falling employment and rising labour productivity. The employees' skills are very low for textiles and are very high for textile products during the post-liberalization period. For the all-India overall period, the labour productivity is recorded at 10 per cent per annum for both the industries. The capital productivity (VO/FC from Table 6) growth is negative for both the industries during all periods. Except Gujarat, Karnataka, Kerala and West Bengal, the remaining states have insignificant growth during the post-liberalization period for textile products.

The average wage of an employee (EML-EMP from table 7) in both the industries for all-India is increasing at 1.7 per cent per annum for the time-span covered in this study. It is also following almost the same trend during the two sub-periods in each of the industries. This ratio is lower and negative during the post-liberalization period compared with the pre-liberalization period for most of the states for both the industries. The rising output per employee resulted in a fall in labour cost per unit of output

Table 7: Annual Compound Growth Rates of Emoluments per Employee and Emoluments per unit of Output for Indian Textile Industry

	Textiles			Textiles products		
	Pre Lib	Post Lib	Overall	Pre Lib	Post Lib	Overall
Emoluments per Employee (EML/EMP)						
India	2.622725	2.196	1.7639	2.299	2.4847	1.7047
Andhra Pradesh	2.6991	–4.7075	–0.3388	5.4894	3.6942#	4.8488
Bihar	5.6699	–0.3818#	0.7638	4.6602	–3.759#	0.1593#
Gujarat	2.613	–4.1534	–0.4531#	5.2891	–0.6999#	3.54
Haryana	2.7253	–4.3371	0.2572#	3.0014	–0.8993#	2.0718
Karnataka	2.6702	0.349#	1.5127	2.3722	–1.9167#	1.057
Kerala	1.3828	0.2053	0.9864	2.1938	2.8309#	–3.6205
Madhya Pradesh	25.722	–3.629	–0.1007#	3.0217	9.226	3.8509
Maharashtra	3.5304	–4.0161	0.6256#	4.1352	–3.7571	1.0937
Orissa	0.2714#	–5.0313	–1.0926	–2.8539	3.8772	0.6347#
Punjab	3.37	–0.5182#	2.4278	4.9637	–3.5876	12.94
Rajastan	2.6545	–2.34	1.1834	1.8285#	4.8017	4.0217
Tamil Nadu	2.3985	–11.1925#	–2.0612#	2.5095	–10.4304#	0.33#
Uttar Pradesh	4.7301#	–3.0373	–0.0593#	0.5009#	0.585#	0.8168
West Bengal	–3.169	–0.8476#	1.4973	4.2031	–1.9742	2.1377
Emoluments per unit of Output (EML/VO)						
India	–8.14509	–6.4858#	–8.3886	–6.4352	–1.1707#	–6.7891
Andhra Pradesh	–8.7045	–3.3536#	–8.7979	–1.9753#	–4.9303	5.2395
Bihar	–1.874#	0.3759#	–2.934	–12.0586	–15.2872	–12.1122
Gujarat	–8.2852	–13.502	–9.8715	–1.6939#	–10.0853	–8.3706
Haryana	–7.8067	–1.5601#	–6.8256	–5.339	–1.0483#	–9.613
Karnataka	–8.5112	–2.2034#	–8.6207	–8.5597	–17.087	–13.402
Kerala	–7.0112	–2.7107#	–7.2112	–0.8068#	–6.5439#	–9.217
Madhya Pradesh	–9.943	–9.7867	–11.7749	–8.37	–20.3795	–12.395
Maharashtra	–6.276	–9.764	–7.6055	–8.5663	–5.4654	–10.943
Orissa	–8.3174	8.0303	–1.8084#	–10.9059	–7.6522	–12.0836
Punjab	–6.6887	–6.3551	–6.8627	2.9559	–12.9712	–6.644
Rajastan	–8.4449	–2.505#	–6.877	–9.0644	–2.1837#	–12.231
Tamil Nadu	–8.3723	–16.3167	–11.5381	6.8274	–18.029	–13.3084
Uttar Pradesh	–7.7083	–3.7262	–8.4243	–6.3902	–10.3008	–10.9389
West Bengal	–4.2577	–6.1674	–4.9556	–7.0995	–14.8208	–11.6611

"#" Denotes Insignificant

(EML-VO). The emoluments per unit of output for textiles have been falling by 7.43 per cent per annum during the overall period whereas it has been declining by 9.8 per cent per annum in the textile products industry.

Though the average wage of an employee in the textile industry showed an increase (except during the post-liberalization period for textiles), the share of emoluments to employees in value added (EML-VA from table 8) declined for both the industries during all the periods. The wage share in value-added has declined by 6.3 per cent per annum for textiles and declined by 11.5 per cent per annum for textile products for all-India. This implies that non-wage share has been increasing in the Indian textile industry. The share of emoluments in value-added has declined faster in textile products than in textiles for all India and across the states.

The value added generated by every unit of output (VA-VO from table 9) in textiles is declining by 2.34 per cent per annum. The fall in VA-VO may be associated with a fall in emoluments per unit of output. Further the

Table 8: Annual Compound Growth Rates of Fixed Capital per Employee and Emoluments per unit of Value-added for Indian Textile Industry

	Textiles			Textiles products		
	Pre Lib	Post Lib	Overall	Pre Lib	Post Lib	Overall
Fixed Capital per Employee (FC/EMP)						
India	26.52281	15.0105	19.2784	26.2403	9.8947	16.3303
Andhra Pradesh	28.7854	11.6258	18.7788	39.5764	3.5373#	17.4451
Bihar	17.7244	–2.985	10.537	32.5322	18.7998	20.6647
Gujarat	26.706	13.6533	18.259	18.4354	16.5129	16.9928
Haryana	25.3842	10.4914	16.0197	27.8093	7.1491	16.9471
Karnataka	30.0317	13.6842	18.5882	27.7445	18.1446	19.6222
Kerala	19.7924	7.4689	13.9798	24.033	11.1908	17.8661
Madhya Pradesh	26.8509	13.8077	21.1522	32.0895	20.8307	22.6125
Maharashtra	25.7224	12.378	18.5445	29.6671	11.9056	18.4345
Orissa	24.2921	4.1082#	12.445	10.5196	21.9197	13.9393
Punjab	30.7667	13.9635	21.0666	20.268	12.6296	14.9319
Rajastan	24.6973	6.4214	16.1822	30.926	13.086	20.855
Tamil Nadu	24.1347	10.31	16.5819	21.6754	13.2572	17.3637
Uttar Pradesh	31.1893	9.4142	20.5776	26.5417	10.6311	16.2936
West Bengal	26.9413	9.8494	17.3357	29.2275	10.2427	20.5658
Emoluments per unit of Value-added (EML/GVA)						
India	–6.85689	–4.9954	–6.79	–9.338	–0.09202	–7.9373
Andhra Pradesh	–7.5664	–5.2417	–7.2717	–7.238	–6.0635#	–8.5223
Bihar	0.0746#	4.914	–1.7542#	–13.948	–22.9766	–13.7052
Gujarat	–6.3561	–12.1023	–7.7356	–6.1756	–6.7859	–9.6421
Haryana	–6.4878	–2.4883#	–5.3985	–9.053	3.6378#	–9.2275
Karnataka	–8.1286	–65.221#	–9.0631	–8.8069	–16.3359	–14.4673
Kerala	–6.7235	–4.2059#	–5.9459	–3.2364#	–7.0259#	–8.0164
Madhya Pradesh	–6.7336	–10.5221	–10.9591	–2.7099#	–25.3552#	–11.9843
Maharashtra	–6.0438	–6.0425	–5.9528	–11.4732	–1.2708#	–13.071
Orissa	–8.2431	10.4746	0.3544#	–9.0055#	–0.8501#	–9.1408
Punjab	–8.4401	–10.8844#	–8.7732	–2.6119#	–19.056	–11.4395
Rajastan	–6.8983	0.4771#	–5.1363	–10.8376	–3.4591#	–14.578
Tamil Nadu	–8.5199	–12.8931#	–9.7687	–11.3006	–16.2459	–15.4772#
Uttar Pradesh	–5.6645	–2.5295#	–6.4793	–7.484	–9.868	–11.7893
West Bengal	–2.9853	–6.7454	–4.8871	–5.246#	–11.362	–10.2351

"#" Denotes Insignificant

fall in VA-VO is faster in the textile industry as compared to the textile products industry, indicating inefficient market institutions, which lead to high market transaction costs.

Conclusions

This paper presents the growth rates of different variables and their ratios for textiles and textile products industries for pre, post-liberalization periods and overall period of the study. The output growth for textiles products is greater than for textiles for all-India during the study period. Further output growth has decreased during the post-liberalization period for textiles, whereas it is higher in textiles products. The acceleration of employment growth is less pronounced than that of output growth for both industries. The growth in fixed capital is low during post-liberalization period when compared to the pre-liberalization period in both the industries for across the states and for all-India. The growth rates of energy and materials consumed are smaller when compared with fixed capital input growth.

All the structural ratios explain the increasing capital

Table 9: Annual Compound Growth Rates of Value-added per unit of Output and Fixed Capital per unit of Output for Indian Textile Industry

	Textiles			Textiles products		
	Pre Lib	Post Lib	Overall	Pre Lib	Post Lib	Overall
Value-added per unit of Output (GVA/VO)						
India	–1.28979	–1.4798	–1.5985	2.9026	–1.1974#	2.1412
Andhra Pradesh	–1.1465	1.9082	–1.5898#	5.2683#	1.1406#	3.2833
Bihar	–1.947	–4.5305	–1.1809#	18.832	27.288#	1.6038#
Gujarat	–1.9312	–1.4438#	–2.1377	4.4799	–3.2945	1.2737
Haryana	–1.312#	0.9229#	–1.4316	3.71	–4.706#	–0.3881#
Karnataka	–0.3817#	–4.3133	0.4432#	0.2464#	–0.6693#	1.0851#
Kerala	–0.2965#	1.4944#	–1.2645	2.4209	0.495#	–1.1994#
Madhya Pradesh	–3.2027	0.7547	–0.8063#	–5.656#	5.0101#	–0.405#
Maharashtra	–0.2336#	–3.712	–1.6479	2.9119	–4.2092#	2.1292
Orissa	–0.0877#	–2.4424#	–2.1627	–1.9015#	–6.7974#	–2.9441#
Punjab	1.7456	4.5518#	1.9149#	5.5626	6.0596#	4.7889
Rajastan	–1.5521	–2.9926	–1.7436	1.7749#	1.2895#	2.3607
Tamil Nadu	0.1527	–3.425	–1.7696	4.4727	–1.8083#	2.469
Uttar Pradesh	–2.045	–1.1944	–19.414	1.0951#	–0.4415#	0.8503#
West Bengal	–1.2773#	0.5864#	–0.0687#	–1.856#	–3.3981#	–1.4152#
Fixed Capital per unit of Output (FC/VO)						
India	15.75419	6.3429	9.124	7.5012	6.2313	5.8346
Andhra Pradesh	17.3878	13.0026	10.3206	32.1126	–5.0893#	7.3534
Bihar	10.1807	7.183	6.837	15.8185	7.299#	8.403
Gujarat	15.8061	4.2937	8.8405	11.4478	7.1214	5.0781
Haryana	14.857	13.2637	8.9351	19.4637	6.997#	5.2601
Karnataka	18.8593	11.1233	8.4508	16.8096	2.9598#	5.1576
Kerala	11.3888	4.5704	5.7819	21.03	1.7814#	12.2657
Madhya Pradesh	14.3332	7.6599	9.4832	20.6992	–8.784	6.361
Maharashtra	15.9271	6.634	10.3192	16.9663	10.181	6.3889
Orissa	15.7025	17.1724	11.73	2.4691#	10.3925#	1.221#
Punjab	20.7146	8.1261	11.7775	18.2613	3.2386	6.9923
Rajastan	13.5978	6.2495	8.1201	20.019	6.0899#	4.6021#
Tamil Nadu	13.3697	5.1894	7.1065	12.3437	5.6787	4.0339
Uttar Pradesh	18.751	8.7151	12.2136	19.6499	–0.2634#	4.5374
West Bengal	19.4939	4.5367	10.879	17.929	–2.5485#	6.7762

"#" Denotes Insignificant

intensity, falling employment, rising labour productivity and falling labour cost for both the industries. Rising wages with falling employment explains the increasing skill composition of the employees which results in an increase in labour productivity. Among 14 major states, Gujarat and Tamil Nadu have been increasing capital intensity and higher skills resulting in rising output per employee.

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Appendix

Data Base

The present study is based on secondary data and covers the period from 1979-80 to 2000-2001. To examine the objectives of the study, the two digit NIC 1987 data has been drawn from various Annual Survey of Industries (ASI) reports published data by Central Statistical Organization (CSO). For the period up to 1997-98 we have used the published data in 'Annual Survey of Industries: A Data-Base on the Industrial Sector in India', EPW Research Foundation, Mumbai, 2002. For the subsequent years up to 2001 the data has been taken from the respective year volumes of ASI.

Until 1997-98 the ASI data was organized according to the NIC 1987 classification and thereafter the NIC 1998 classification has been followed. As we are working with NIC 1987 to arrive at a consistent data set at the two-digit level we have used the concordance published by the CSO to reclassify the data for the years 1998-99, 1999-2000 and 2000-2001 according to NIC 1987.

In the study we have taken two industries viz., textiles and textile products. We make up the 'Textiles' by adding the NIC 1987 two digit codes of Manufacture of Cotton Textiles (23), Manufacture of Wool, Silk and Man-made Fibre Textiles (24) and Manufacture of Jute and Other Vegetable Fibre Textiles (except cotton) (25). The NIC 1987 code 26 'Textile Products' taken as it is.

Keeping in view of the study objectives we have collected the time series data on value of output, fixed capital, number of employees, total emoluments, fuel and material consumed of the textile products and manufacture of textiles for 14 major states and for all India.

Deflators

Since the data collected are at current prices, to bring the data into constant prices, we have used appropriate deflation techniques for the different variables. To bring the data into constant prices, we have taken 1981-82 as the base year for both industries throughout the study.

The value of output is deflated by the wholesale price index of industrial production. For estimating the capital stock, the present study adopts the standard practice of perpetual inventory method. According to this method capital stock for a given year is traced by adding the previous investments starting from benchmark year, converting to constant value by a price index for capital assets. The bench mark year for the present study is 1979-80 as the study covers the period from 1979-80 to 2000-2001. Following Banerji (1975), Goldar (1986) and Balakrishnan (1994), double of the book value of the fixed capital is taken as a measure of capital stock for the base year. For the subsequent years, gross real investment has been taken as a measure for capital stock. Annual gross investment series is constructed by adding depreciation to the net fixed capital stock as reported in the ASI. This gross investment series is deflated by capital price index which has taken as 'industrial machinery for food and Textiles' a proxy of machinery price index.

The gross investment series is obtained, for the year 't' at 1981-82 prices, as

$$I_t = (B_t - B_{t-1} + D_t)/P_t$$

B_t is the book value of the fixed capital in the t^{th} year, B_{t-1} is book value of the fixed capital in the $(t-1)^{th}$ year, D_t is Depreciation in i^{th} year and P_t is Price index for machinery for the t^{th} year with year 1981-82 base.

After constructing the gross investment series the capital stock at year 't' is obtained by

$$K_t = K_o + \sum I_t$$

where 'K_o' is capital stock in the base year and 'I_t' is gross real investment.

Following Jha, Murty & Paul (1991), Danish A Hashim (2004) the price of capital services is measured as follows:

$$Pk_t = PI_t (d_t + r_t)$$

where Pk_t = Price of Capital in year 't', PI_t is the price of Investment goods, d_t is the depreciation rate for the year 't', r_t is the rate of interest (the long term lending rate of the IDBI)

The total emoluments are deflated by the consumer price index for industrial workers. The variable energy has been deflated with weighted price index for energy, which is constructed with relevant weights and wholesale price indices of mineral oil and electricity. In order to deflate the series on materials consumed we have constructed industry specific material price indices. Using the input-output table of 1993, we have taken the five components, which are used in the production process of textiles and textile products.

□

You can tell whether a man is clever by his answers. You can tell whether a man is wise by his questions.

– Naquib Mahfouz

Feature

Growth Performance and Productivity of Leather Industry in Punjab

Sanjeev Gupta & Gulshan Kumar

This paper examines the need to take strategic policy measures to improve the productivity of the Indian leather industry. A study has been made of the growth behaviour in a number of units, fixed investment, employment, export, production, partial productivity of labour and capital, capital output ratio and capital intensity of the leather industry of Punjab. A SWOT analysis was conducted to help policymakers build on the strengths of the leather industry.

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The leather industry occupies a place of prominence in the Punjab economy, in view of its enormous potential for employment, growth and exports. The leather industry in Punjab with its various advantages such as rich raw material base, cheap labour and trained professionals, is poised for a leap ahead. Jalandhar in Punjab is the major production centre for leather and leather products and this industry has shown tremendous growth in and around Jalandhar. There has been a growing emphasis on its planned development, aimed at optimum utilization of existing raw materials for maximizing the returns, particularly from exports.

Leather is a natural, three dimensional non-woven fabric, which is not easily or completely duplicated. The utility of leather is attributed to its specific properties such as strength, comfort, durability and breath ability. Leather yields an exceptional fullness and soft handle while providing high temperature and ultraviolet resistance (Tribune March 8, 2006).

The leather industry is organized into tanning, footwear and footwear components, leather garments, leather goods, saddler and harness articles (K. Elangovan, 2006). Leather processing has brought about a revolution with the art of wear fashion. Starting from footwear, today leather is used to make bags, handbags, trunks, suitcases, gloves, folios, belts, travelware, rucksacks, wallets, upholstery, sports and industrial products including luxury items.

The leather industry is organized into tanning, footwear and footwear components, leather garments, leather goods, saddler and harness articles.

The leather industry has undergone a spectacular transformation from a mere exporter of raw materials in the sixties to that of value added finished products in the nineties. In the wake of globalisation of the Indian economy, supported by the liberalised economic and trade policies since 1991, the industry is poised for further development. In the year 1980-8 in the leather industry of Punjab, total numbers of units were merely 2478, which grew to 13,114 in 1990-91 and was further augmented to 14,810 in 2003-04. In the year 1980-81 total production of leather industry in Punjab was Rs 48 crore, which improved to Rs 118.33 crore in the year 1990-9 and further enhanced to Rs 398.27 crore in the year 2003-04. When we talk about fixed investment in the leather industry of Punjab, it was Rs 4.08 crore in the year 1980-81and escalated to Rs 94.55 crore in 2003-04. The leather industry is one of the fastest growing industries and the largest foreign exchange earner in the country. The export of leather industry in Punjab was Rs 3.23 crore in the year 1980-81, which increased to Rs 79.29 crore in 1996-97 and further achieved the uppermost figure of Rs 205.70 crore in the 2001-02 and finally decelerated sharply to Rs 66.42 crore due to fierce competition in international market from countries like China, Vietnam, Thailand, Indonesia, etc. On the front of employment generation 8,349 people were directly employed in the year 1980-81 and the total number of employed personnel was 39,739 in the year 2003-04 (Directorate of Industries, Punjab, 2005).

The leather industry has undergone a spectacular transformation from a mere exporter of raw materials in the sixties to that of value added finished products in the nineties.

A number of researchers like Beri (1962); Raj Krishan (1968); Dandekar (1980); Krishnaji (1980);Bawa and Kainth (1980); Gupta(1973) ;Mehta (1973); Brahmanada (1982); Deepak Gupta (1985); Golder (1986); Ahluwalia (1991); Deepak Gupta (1990); Sanjeev Gupta (1993); Jayalakshmi (1988); Sanjeev Gupta (2002); Balakrishnan(2003); Golder(2003); Venkataramaiah (2003); Golder (2004) and Veermani (2005) have estimated the growth trends and productivity in Indian manufacturing sector at aggregate and disaggregate level, by using compound growth rates, partial and total factor productivity indices. But in this paper, an attempt has been made to study the growth behaviour in number of units, fixed investment, employment, export and production, partial productivities of labour & capital, capital output ratio and capital intensity of leather industry of Punjab in order to make policy makers aware and to have a more realistic understanding of the future prospects of leather industry.

Objectives of the study

Academicians, planners and policy makers have stressed the need to comprehend the analysis of growth performance and productivity to frame a sound industrial development strategy. In this paper attempt has been made to make policy makers aware about the profile of leather industry in Punjab.

The specific objectives of the study were:

1. To capture the changes in pace and pattern of growth momentum in number of units, fixed investment, employment, export and production during pre-liberalisation and liberalisation and overall periods
2. To compute productivity of labour, capital, capital output ratio and capital intensity and to examine prevailing trends in them.
3. To analyze comparative picture of growth performance of number of units, fixed investment, employment, export and production during pre-liberalisation, liberalisation periods.
4. To carry out Strength, Weaknesses, Opportunities and Threats (SWOT) analysis of leather industry.

Database and analytical framework

The present study is based on secondary data for the period of 24 years i.e. 1980-81 to 2003-04. The data relating to number of units, employment, export, fixed capital and production of leather goods industry at aggregate level for the said period were culled from Directorate of Industries, Punjab. (Data for the next years were still under computation as there is manual calculation of figures at Directorate of Industries, Punjab). Since the figures of export, fixed capital and production were given at current prices, these have been converted into constant prices by deflating them with index number of the wholesale prices of manufactured products total, taking 1993-94 as the base year. Yearly growth rates for all the five variables were computed to capture year-to-year fluctuations in growth.

Partial productivities of labour and capital were obtained as O/L and O/K. For making an assessment of

the extent of amount of units of capital that are needed to produce a certain level of output and capital intensity K/L and K/O ratios were also computed. Compound Annual Growth Rates (CAGRs) were for overall period (1980-81 to 2003-04) and two sub-periods: pre-liberalisation (1980-81 to 1991-92) and liberalisation periods (1991-92 to 2003-04) for all the nine variables were estimated by fitting an exponential function of the following form:

$$Y_t = \beta_0 \beta_1^t e^{Ut} \quad \ldots (1)$$

where Y_t is dependent variable, β_0 and β_2 are the unknown parameters, and U_t is the disturbance term. The equation (1) could be written in the logarithmic form as follows:

$$\log Y_t = \log \beta_0 + t \log \beta_1 + U_t \quad \ldots(2)$$

The above equation was estimated by applying Ordinary Least Square Method and compound rate of growth (gr_c) was obtained by taking antilog of estimated regression coefficient, subtracting 1 from it and multiplying the difference by 100, as under:

$$gr_c = \left(A.L.\hat{\beta}_1 - 1\right) \times 100 \quad \ldots(3)$$

where $\hat{\beta}_1$ is an estimate for β_1. The significance of growth rates was tested by applying t – test, given as follows:

$$t = \frac{\hat{\beta}_1}{s(\hat{\beta}_1)} \sim t\ (n-2)\ \text{d.f.} \quad \ldots(4)$$

where $\hat{\beta}_1$ is the regression estimate, $s(\hat{\beta}_1)$ the respective standard error. All statistically non-significant growth rates are treated as almost zero growth rates.

Research Findings

The first sub-section is devoted to an analysis of compounds annual growth rates of number of units, employment, export, fixed capital and production. Moreover, yearly growth rates were also calculated to capture the year-to-year fluctuations. The second sub-section is devoted to the profile of capital intensity, capital-output ratio and partial productivities of labour and capital in leather goods industry. The third sub-section deals with a SWOT analysis of leather industry.

Growth Performance

Measuring growth has been one of the most extensively researched areas. The growth rate analysis helps in evaluating development programmes, which were launched with specific objectives over specific time. A positive growth rate reveals an increase related aspect by its magnitude per annum, whereas the opposite is case for negative growth rates. All the statistically non-significant growth rates indicate that there is no growth at all (Krishnaji; 1980). The year-to-year growth rates and compound annual growth rates of number of units, fixed investment, employment, export and production of leather industry are shown in Table I. The results have been discussed in brief under the following five sub-heads:

A positive growth rate reveals an increase related aspect by its magnitude per annum, whereas the opposite is the case for negative growth rates. All the statistically non-significant growth rates indicate that there is no growth at all.

Number of Units

Perusal of Table I indicates that the year-to-year growth rate of the number of units of the leather industry depicted almost a trend of deceleration during the study period. The rate of growth was quite high in the year 1981-82 i.e. 65.86 per cent. It experienced a steep fall and touched the level of 6.81 per cent in 1988-89. Depicting marginal acceleration in the next year, further it presented a wavering scenario till 1992-93 when it became just 1.46 per cent. Showing no change in the next year, the year-to-year rate of growth became almost negligible till 2001-02 i.e. 0.08 per cent. In 2002-03, the rate of growth moved up to 1.93 per cent but in 2003-04, it again dropped to 0.08 per cent. Further perusal of Table I reveals that the CAGR of number of units achieved a significant growth of 14.33 percent in pre-liberalisation period but showed a steep deceleration to 0.33 per cent in liberalisation period. In case of overall period number of units showed of compound growth rate of 5.33 per cent annually.

Employment

Analysis of Table I reveals that the year-to-year rate of growth of employment followed a declining trend during the study period. A significant rate of growth of 33.5 per cent in 1981-82 depicted deceleration to 32.31 per cent in 1982-83 and it continued till 1986-87 to become 8.13 per cent. Showing marginal acceleration in the next year, it became 8.46 per cent. Afterwards, presenting a

Table I: Year-to-Year and Compound Annual Growth Rates of Leather Industry (in per cent)

Year	No. of Units	Employ-ment (In no.)	Fixed Invest-ment (In Rs. Cr.)	Exports (In Rs. Cr.)	Produc-tion (In Rs. Cr.)
1980-81					
81-82	65.86	33.5	45.71	61.09	21.54
82-83	39.51	32.31	14.57	-14.76	3.18
83-84	25.92	24.13	19.22	0.44	4.7
84-85	17.71	18.93	12.96	45.73	6.7
85-86	11.97	10.64	10.71	-12.95	-0.23
86-87	8.82	8.13	21.3	16.93	10.83
87-88	6.81	8.46	12.87	-6.71	-3.26
88-89	6.84	5.48	1.62	105.2	-4.97
89-90	5.32	3.87	-3.14	-0.49	-7.66
90-91	5.37	2.89	2.37	23.81	-2.8
91-92	7.34	4.77	2.37	-9.67	-6.45
92-93	1.46	1.16	-8.97	19.3	-4.2
93-94	0	0.89	-2.94	8.42	14.94
94-95	0.33	1.19	-4.89	11.97	19.96
95-96	0.46	0.78	0.95	-16.91	-25.34
96-97	0.19	0.68	11.23	47.22	10.02
97-98	0.21	0.46	2.77	26.65	3.54
98-99	0.1	0.41	-1.17	-23.89	3.32
99-2000	0.1	0.46	6.49	34.71	3.77
2000-01	0.17	1.14	2.73	0.2	5.56
2001-02	0.08	0.32	1.33	71.7	2.49
2002-03	1.93	9.45	51.1	-38.58	28.32
2003-04	0.08	1.02	2.67	-51.48	3.73
CAGRs					
1980-81 to 1991-92	14.33*	12.3*	11.31*	14.45*	1.22*
1991-92 to 2003-04	0.33*	1.21*	4.28*	6.63*	3.99*
1980-81 to 2003-04	5.33*	4.9*	4.65*	10.85*	1.36*

* Significant at 5 per cent level of significance.

** Insignificant at 5 per cent level of significance

fluctuating picture, it became negligible i.e. 0.32 per cent in 2001-02. This meagre growth figure was replaced by a significant growth figure of 9.45 per cent in the year 2002-03. The year-to-year rate of growth once again showed deceleration to 1.02 per cent in 2003-04. Further examination of Table I depicts that the CAGR of employment was 12.3 per cent in the pre-liberalisation period but decelerated to 1.21 per cent in the liberalisation period. In the overall period, employment grew annually at the rate of 4.9 per cent.

Fixed Investment

Perusal of Table I exhibits that the year-to-year rate of growth of fixed investment was very high i.e. 45.71 per cent in the year 1981-82, but that it continued to fall till 1985-86 when it became 10.71 per cent. The year-to-year rate of growth showed acceleration to 21 per cent in the next year but further it declined and depicted a dejectedly low of 1.62 per cent in the year 1988-89. This positive rate of growth got replaced by a negative figure of -3.14 per cent in the year 1989-90. A good deal of fluctuations can be discerned in the year-to-year rate of growth till it touched an all time high level of 51.1 per cent in the year 2002-03. This splendid figure also got replaced by a very low growth rate of 2.67 per cent in the year 2003-04.

Further analysis of Table 1 depicts that the CAGR of fixed investment experienced a steep deceleration from 11.31 per cent during the pre-liberalisation period to 4.28 per cent during the liberalisation period. The overall CAGR has remained 4.65 per cent.

Exports

Conspicuous perusal of Table 1 depicts that the year-to-year growth rate of exports dropped from a very high rate of growth of 61.09 per cent in 1981-82 to a negative rate of growth of -14.76 per cent in 1982-83. A positive figure of 0.44 per cent replaced this negative rate of growth in 1983-84. After encompassing a steep acceleration, the rate of growth became 45.73 per cent in 1984-85. Afterwards, depicting a fluctuating scenario, the rate of growth touched an all-time high of 105.2 per cent in the year 1988-89. But in the next year, this splendid figure got replaced by a negative rate of growth of -0.49 per cent. A good extent of fluctuations continued to appear till the rate of growth became almost negligible i.e. 0.20 per cent in the year 2000-01. Next year, the rate of growth of exports increased steeply to 71.7 per cent. Again a negative figure of the order of -38.58 per cent replaced the positive rate of growth in 2002-03. In the next year 2003-04, the rate of growth further decelerated to -51.48 per cent.

In the case of CAGR's perusal of Table 1 revealed that the rate of growth of exports was 14.45 per cent in the pre-liberalisation period but that it plunged to 6.63 per cent in the liberalisation period. In case of the overall study period exports grew annually at the rate of 10.85 per cent.

Production

A glance of Table 1 highlights that the year-to-year

rate of growth of production was high i.e. 21.54 per cent in the year 1981-82. This registered a steep deceleration in the next year, and it recovered marginally and became 6.7 per cent in the year 1984-85. A negative growth rate of -3.26 per cent was replaced by a positive rate of growth in 1985-86. Except for the year 1986-87, the rate of growth continued to be negative till 1992-93. After that it again picked up and became 14.94 per cent in 1993-94 and further accelerated to 19.96 per cent in 1994-95. Again the rate of growth turned negative i.e. -25.34 per cent in the year 1995-96. The year-to-year rate of growth of production shows a positive growth of 10.02 per cent in the year 1996-97, but presented a wavering picture with marginal fluctuations and achieved a growth rate of 2.49 per cent in 2001-02.

Achieving an all-time high rate of growth of 28.32 per cent in 2002-03, it moved from zenith to 3.73 per cent in the year 2003-04. Further perusal of Table 1 depicts that the CAGR of production has achieved a growth of 1.22 per cent in the pre-liberalisation period and further accelerated to 3.99 per cent in the liberalisation period. In case of the entire period of study CAGR has increased annually at the rate of 1.36 per cent.

The conclusion emerges from the above discussion that the rate of growth of number of units, employment, fixed investment and exports have showed deceleration during liberalisation period in comparison with the pre-liberalisation period. It is only in the case of production that liberalisation has shown a positive impact i.e. the rate of growth of production has depicted acceleration during liberalisation period in comparison with pre-liberalisation period.

Rate of growth of number of units, employment, fixed investment and exports have shown a deceleration during the liberalisation period. It is only the case of production that liberalisation has shown a positive impact.

Profile of Productivity and Related Variables

Productivity is the relationship between economic output and the inputs, such as labour and capital, which has gone into producing that output. It is clear that the capacity of the economy to produce goods and services depends on the stock of factor resources available plus the productivity of those factors. Productivity can be increased through better utilization of resources. It is widely agreed that increasing productivity is a good thing. Improvements in labour and capital productivity allow businesses to produce output at a lower average cost (i.e. exploit economies of scale). From improved productivity, businesses can develop (or protect) a competitive advantage.

Table 2 depicts the profile of capital intensity, capital-output ratio and partial productivities of labour and capital in leather industry of Punjab. Table III highlights the compound annual growth rates of capital intensity, capital-output ratio and partial productivities of labour and capital in leather goods industry. The details have been furnished under the following four sub-heads:

Capital Intensity

Capital intensity is the amount of capital per unit of labour input. Capital intensity represents degree of mechanization in an industry. The higher the capital intensity the higher will be the degree of mechanization. A glance at column 2 of Table 2 depicts that capital intensity was 0.0013 in the year 1980-8 and became 0.0014 in 1981-82. Further analysis of Table 2 reveals that it kept on fluctuating and decelerated to 0.0009 in 1995-96, that it further continued to increase and finally settled at 0.0015 in the year 2003-04.

Perusal of Table 3 reveals that during pre-liberalisation period, the rate of growth of capital intensity was -1.25 per cent. Compound annual growth rate of capital intensity turned positive from negative and increased annually at the rate of 2.94 during the liberalisation period. For the entire study period capital intensity showed a deceleration of -0.26 per cent.

Capital-Output Ratio

Capital-output ratio shows the amount of units of capital that are needed to produce a certain level of output. If the capital stock is growing faster than output, the capital-output ratio rises; if it is growing slower, the capital-output ratio falls. It infact represents the degree of efficiency of capital. Low value of capital-output ratio is desirable everywhere. Assessment of column third of Table II reveals that capital-output was just 0.008 in 1980-81 and started increasing and attained the figure of 0.25 in the year 1991-92. It declined to 0.16 in the year 1994-95 and started improving afterwards and finally settled at 0.24 in the year 2003-04.

Perusal of Table 3 depicts that the CAGR of capital-output ratio during the pre-liberalisation period was 10.41 per cent, but that under the impact of liberalisation it

became very low i.e. 0.29 per cent. For the overall period i.e. from 1980-81 to 2003-04, the capital-output ratio grew at the compound rate of 3.35 per cent per annum.

Capital Output ratio shows the amount of units of capital that are needed to produce a certain level of output. If the capital stock is growing faster than output, the capital-output ratio rises; if it is growing slower, the capital-output ratio falls. It in fact represents the degree of efficiency of capital. Low value of capital-output ratio is desirable everywhere.

Partial Productivity of Capital

Capital productivity is measured as the amount produced per unit of capital employed. Perusal of Table II depicts that the figure of capital productivity was 11.77 in the year 1980-81 after that it started declining and touched the level of 4.00 in the year 1990-91. After that during globalisation period it showed slight improvement and reached at 4.91 in the year 2001-02 and finally it decelerated marginally and attained the value of 4.21 in 2003-04.

Column third of Table 3 depicts the compound annual growth rates of capital productivity. During the pre-liberalisation period capital productivity has shown a steep deceleration of 9.07 per cent and capital productivity has shown an improvement in deceleration during globalisation period as compared to the pre-globalisation period. For the entire period of study CAGR has shown negative growth rate of 3.15 per cent.

Partial Productivity of Labour

Labour productivity measures how much output is obtained per employee and is considered a key measure of economic efficiency. It is also closely linked to economic growth as well as per capita income. Output per worker (labour productivity) is usually measured as reasonable amount produced per employee. Productivity of labour has revealed a continuous decline, but during the globalisation period it has shown a slight improvement as compared to the pre-globalisation period. Perusal of Table 2 depicts that amount of labour productivity was 0.0147 in the year 1980-81 and it after minor upward fluctuations finally decelerated to 0.0064 in 2003-04.

Analysis of Table 3 depicts that productivity of labour in leather industry experienced negative CAGR of -9.89 percent prior to the adoption of liberalisation policy by government of India. Under the impact of liberalisation, CAGR turned positive from negative and grew annually at compound rate of 2.7 per cent. For the overall period of 1980-81 to 2003-04 compound growth rate has decelerated to -3.37 per cent per annum.

On the basis of the above discussion, we can conclude that liberalisation has given a push to mechanization in the leather industry of Punjab. Capital-output ratio has also fallen under the impact of new policies. As far as factor productivities are concerned, they depicted an improvement during in liberalisation period in comparison with the pre-liberalisation period.

SWOT Analysis of Leather Industry

SWOT stands for Strengths, Weaknesses, Opportunities and Threats. A SWOT analysis is a written exercise that will help to clarify and focus on the specifics that make up the four areas that most affect leather industry. The purpose of a SWOT analysis was to help policy makers build on strengths, helps them to identify ways to minimize and correct the affect of weaknesses of the leather industry, and take the greatest possible advantage of potential opportunities while formulating a plan to deal with potential threats.

Strengths - Strengths are those things that make the business stronger. In the strength analysis we are going to examine what advantages the leather industry has its counterparts. The following points highlight the strengths of the leather industry:

- High growth oriented industry
- Ready availability of highly skilled, qualified and cheap manpower
- Large raw material base as compared to other competitors
- Policy initiatives taken by the Government to give boost to the leather industry after realizing its export potential
- Capability to incorporate new technologies and handle huge projects
- Incessant emphasis on product development and design up gradation
- Ownership of patents and trademarks
- An established customer base
- A good reputation in the international market

Table 2: Profile of Capital Intensity, Capital-Output Ratio and Partial Productivities of Labour and Capital in Leather Goods Industry

Year	K/L[1]	K/O[2]	O/K[3]	O/L[4]
1980-81	0.0013	0.08	11.77	0.0147
81-82	0.0014	0.1	9.82	0.0134
82-83	0.0012	0.11	8.84	0.0105
83-84	0.0011	0.13	7.76	0.0088
84-85	0.0011	0.14	7.33	0.0079
85-86	0.0011	0.15	6.61	0.0071
86-87	0.0012	0.17	6.04	0.0073
87-88	0.0013	0.19	5.17	0.0065
88-89	0.0012	0.21	4.84	0.0059
89-90	0.0011	0.22	4.61	0.0052
90-91	0.0011	0.23	4.38	0.0049
91-92	0.0011	0.25	4	0.0044
92-93	0.001	0.24	4.21	0.0042
93-94	0.001	0.2	4.99	0.0048
94-95	0.0009	0.16	6.29	0.0056
95-96	0.0009	0.21	4.65	0.0042
96-97	0.001	0.22	4.6	0.0046
97-98	0.001	0.22	4.64	0.0047
98-99	0.001	0.21	4.85	0.0048
99-2000	0.0011	0.21	4.72	0.005
2000-01	0.0011	0.21	4.85	0.0052
2001-02	0.0011	0.2	4.91	0.0053
2002-03	0.0015	0.24	4.17	0.0063
2003-04	0.0015	0.24	4.21	0.0064

1. Capital Intensity (K/L): It is fixed capital at constant prices per employee
2. Capital Output Ratio (K/O): It is ratio of total fixed capital to total production (both deflated)
3. Partial Productivity of Capital (O/K): It is ratio of total production to total fixed capital (both deflated)
4. Partial Productivity of Labour (O/L): It is total production at constant prices per employee

Table 3: Compound Annual Growth Rates of Capital Intensity, Capital-Output Ratio and Partial Productivities of Labour and Capital in Leather Goods Industry

1980-81 to 1991-92	-1.25*	10.41*	-9.07	-9.89
1991-92 to 2003-04	2.94*	0.29**	-0.28	2.70*
1980-81 to 2003-04	-0.26**	3.35*	-3.15*	-3.37

* Significant at 5 per cent level of significance

** Insignificant at 5 per cent level of significance

- Use of information technology and decision support software to help eliminate the length of the production cycle for different products
- Use of e-commerce in direct marketing

Weaknesses - Weaknesses are the antitheses of strengths. Weaknesses are those areas in which the existing leather industry does not perform well. The following points highlight the weaknesses of the leather industry:

- Lack of warehousing support from the government
- International price fluctuations and aggressive competitors
- Huge labour force resulting in high labour charges
- Lack of strong presence in the global fashion market
- Unawareness of international standards by many players resulting in poor products or services
- Lack of marketing and sales expertise
- Lack of capital
- Poor and unprofessional management of the units

Opportunities - Opportunities are those things that have the potential to make the business stronger, more enduring and more profitable. The following points highlight the opportunities available to the leather industry:

- Rising potential in the domestic market
- Growing fashion consciousness globally
- Expanding old markets
- Strategic alliances

Threats - By looking both inside and outside, threats are those things that have the potential to adversely affect leather industry of Punjab. The following points highlight the threats to the leather industry of Punjab:

- Limited scope for mobilizing funds through private placements and public issues
- Changing marketplace conditions due to high competition from East European and other Asian countries
- Competitors with lower prices

- Laws and/or taxes that may have negative impact on industry;

Concluding Remarks

No doubt, Punjab is an agro-based state but it has also carved out a niche for itself as an industrial economy, especially in the small-scale sector. The policy of liberalisation, privatisation and integration of the world economics was expected to provide fillip to the small-scale sector, in terms of increased investment, more employment opportunities and strong marketing network. But the analysis of the performance of the leather industry has depicted a different story. In absolute terms over a period of time, the number of units, fixed investment, employment, exports and production has increased. But the analysis of growth performance of the above mentioned five variables during pre-liberalisation, liberalisation and overall periods have revealed the true state leather industry in Punjab. During the entire period of 1980-81 to 2003-2004, all the five variables have depicted significant growth. The comparative picture of pre-liberalisation and liberalisation periods demonstrated that the economic reforms and liberalisation process has resulted in slow growth of leather industry due to the fierce competition from foreign players. During the liberalisation period only production has resulted in accelerated rate of growth as compared to the pre-liberalisation period. On the front of employment leather industry, growth rate of employment has shown steep deceleration during the liberalisation period. It could be envisaged from the analysis that liberalisation has resulted in jobless growth because along with an acceleration in the growth of production, the rate of growth of employment has gone down drastically.

The profile of labour and capital productivity indicates in absolute terms partial productivity of labour and capital has gone down, whereas capital output ratio has improved and capital intensity has almost remained at same level after depicting fluctuations. The comparative profile of pre-liberalisation and liberalisation depicted that during liberalisation productivities of labour and capital and capital intensity has improved significantly, whereas the capital output ratio has steeply decelerated.

Keeping into consideration growth, productivity and the SWOT analysis of the leather industry of Punjab, our policy maker will have to take strategic measures for further strengthening its base. In this regard, a serious endeavour should be made to attract private and foreign investment, there should be an emphasis on R&D efforts, the entire processing chain of leather should be exempted from the levy of service tax, rejuvenating and strengthening the existing units, modernization and upgradation of technology in the processing of leather, marketing support and integration of information technology, automation and networking for improving overall productivity and efficiency of leather industry. To sum up, all-out, concerted efforts are required on the part of the State Government for improving the upshot of the leather industry and steps taken in isolation will not yield the desired results.

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What will become compellingly important is absolute clarity of shared purpose and a set of principles of conduct—a sort of institutional genetic code that every member of the organization understands in a common way and with deep conviction.

– Dee Hock

Feature

Implications of WTO Regime on Small Scale Industries

Rajni Sharma & J P Sharma

The World Trade Organization (WTO) Regime came into existence on 1st January 1995 following the Uruguay Round of Negotiations under the aegis of General Agreement on Tariffs and Trade (GATT). The regime brings threats as well as opportunities in terms of increased avenues of exports. The present study examines government policy and desirable policy changes if any, and shows that the WTO regime has turned out to be an opportunity for the SSI sector rather than a threat.

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Small Scale Industries (SSI) play a vital role in the process of growth in developing countries like India. These are considered to be the powerful instruments of economic decentralization, employment generation and dispersal of industries over different regions. For a country faced with growing unemployment, the contribution of the SSI sector is not only economic but social also. The SSI sector has played and has the potential to play a vital role in the fulfillment of our socio-economic objectives.

This sector accounts for 95 per cent of industrial units in the country; 39.07 per cent of value added in the manufacturing sector; 33.97 per cent of national exports and 6.29 per cent of Gross Domestic Product (GDP). Other features include employment to 193,000 persons, production of over 7500 items, product range varying from simple items produced with traditional technology to high-tech products produced with sophisticated state of the art technology, 749 items reserved for exclusive manufacture in the SSI sector and 358 items reserved for exclusive purchase from the SSI sector (SIDO: Aug 2002).

In India, majority of the SSI units are in the nature of tiny micro-enterprises and are weak. Many of them are one-man shows. Their capital base is poor and they do not have economies of scale. Their bargaining power is low and they do not have access to information and modern management practices. Some of the SSI units are comparatively larger and better equipped to face uncertainties but they are also tiny when compared to the SSI sector of developed countries (Prasad, C.S: 2000).

WTO Regime: New Challenges and Changing Policy Parameters

The World Trade Organization (WTO) Regime came into existence on 1st January 1995 under the Marrakesh

Agreement, following the Uruguay Round of Negotiations under the aegis of the General Agreement on Tariffs and Trade (GATT). Changes in policy parameters as a result of the WTO regime affecting SSIs are removal of Quantitative Restrictions (QRs), gradual opening of reserved categories of items and putting them in Open General License (OGL) for imports, lowering of tariffs, gradual removal of subsidies, legislation on Trade Related Intellectual Property Rights (TRIPS), copyrights and trademarks, application of technical, labour and environment standards. The process of phasing QRs had been triggered by India's agreement with the USA for fazing out all QRs. This had direct implications in terms of the reserved list of products for protecting SSIs and the competition from imports that is under way (Mukherjee, Neela: 2001).

With the removal of QRs, tariff protection has also come down significantly. India is committed to a ceiling tariff binding of 40 per cent on finished goods and 25 per cent on intermediate goods, machinery and equipment (Nag, Biswajit: 2000). A phased reduction to these bound levels has also thrown up a challenge to the Indian small scale industry.

The maximum rate of import duty has been reduced gradually from 150 per cent in 1991-1992 to 40 per cent in 1997-1998. The gradual reduction in import duties has led to a significant decline in the protection of Indian industry. The average value of effective rate of protection through tariff has declined from 90 per cent in the pre-reform period to round 24 per cent in 1997-1998 (IIFT: 1999).

The WTO regime brings threats as well as opportunities. It offers opportunities in terms of increased avenues of exports. Therefore, it becomes imperative to analyse the impact of the WTO regime on SSIs in India.

Methodology

Northern India (mainly Delhi, UP and Haryana) which is the most prominent and thriving region as far as SSIs is concerned, was selected for the study. The selection was also guided by easy access and convenience. The following three sets of questionnaires were designed:

(i) Questionnaire for office bearers of industry associations to have an overview of overall impact of WTO regime on the entire SSI sector.

(ii) Questionnaire for the owners of auto component manufacturing units.

(iii) Questionnaire for the owners of plastic processing units.

Questionnaire which contained close-ended as well as open ended questions was designed in consultation with SSI wings of CII, FICCI, ASSOCHAM, PHDCCI and various officials of WASME. Office bearers of FASSI and Laghu Udhog Bharti were also involved. Effort was made to keep the questionnaire small and simple to evoke quick response. Visits to various industrial areas in the vicinity of Delhi, U.P. and Haryana were made and personal interviews were conducted. Interviewing method was used predominantly. The addresses of prominent industry associations were taken from the office of SIDBI.

Sample was chosen in accordance with prevalent ownership pattern of units in SSI (for IInd and IIIrd Questionnaire). All the sample units have been in business for at least five years. So they know reasonably well about the industry and they belong to the group which has survived the critical years. Response could be had from 100 office bearers of various industry associations. In case of auto component sector, the response could be had from 110 units and in case of plastic processing sector, from 95 units. Secondary data is collected from Economic Surveys, India Trades (Database) CMIE, website of Ministry of Commerce, Custom Tariff Manual (to know tariff rate and import policy), publications of Industry Associations, website of SIDO (to update dereservations), website of WTO, etc.

Years chosen are from 1993-94 to 2002-03. Though WTO came into existence in 1995, the base year chosen was 1993-94, to have proper reflection of the changing regime after the reform process started in 1991.

Limitations of the study

The study mainly suffers from the following limitations:

(i) The major limitation of the study was the hesitation on the part of the entrepreneurs to share the actual data with an outsider. This limitation has been partially removed by designing the questionnaire in such a way that qualitative information was sought which could be later codified quantitatively.

(ii) The study is confined to three Northern states only, namely Delhi, Uttar Pradesh and Haryana.

Results of the Study

Results of the questionnaire based on survey are reproduced in the form of tables given below to give a better depiction and understanding.

Table 1: Perception Towards WTO Regime

	Count
Threat	10
Opportunity	05
Opportunity as well as Threat	85
Total	100

The results show that there is a mixed feeling towards the WTO regime. Most of the respondents felt that the WTO regime might be an opportunity or threat depending on the specific industry in which one operates, but if one speaks of the SSI units as a whole then it has to be considered as an opportunity as well as a threat because it has benefited certain industries while it has harmed some others. Thereby one can conclude that the WTO regime is an opportunity as well as a threat.

Hypothesis to be Tested: "Awareness regarding WTO regime is abysmally low among small-scale entrepreneurs."

The following table depicts the awareness amongst small-scale entrepreneurs regarding the WTO regime:

Table 2: Awareness Regarding WTO Regime

Class Interval	Count
0 - 20%	Nil
20 - 40%	70
40 - 60%	20
60 - 80%	10
80 - 100%	Nil
Total	100

According to 70 per cent of respondents, only 20-40 per cent of SSI entrepreneurs are aware of the WTO regime. Office bearers of industry associations stated that most of the SSI entrepreneurs just know the fact that the WTO exists. The only source of this information is also either from their personal experience or from friends. On further interrogation regarding the reasons for such a low level of awareness they said that the Government and its institutional framework has failed badly in its WTO sensitization programmes. Also, these programmes were limited to the conference rooms only.

It is advised that such sensitization programmes should have been conducted beforehand and in large numbers, at places convenient to the entrepreneurs for example in their own industrial area. The literature on the WTO regime and various agreements under the WTO regime could have been distributed in those areas. If not all entrepreneurs could be involved in such conferences at least office bearers of the associations ought to have been involved, so that they could engage themselves in the process of dissemination of information to each and every member of the association. The approach followed was not proactive and rather reactive and that too only in order to meet bureaucratic requirements rather than the needs of industry.

There is sufficient evidence to accept the hypothesis that awareness level is very low. Therefore, the hypothesis is accepted that awareness about the WTO regime is abysmally low among small-scale entrepreneurs.

Hypothesis to be Tested: "WTO regime is responsible for increase in the rate of sickness and closure of units within SSI."

The following table depicts the rate of sickness in the SSI sector that may be attributed to the WTO regime:

Table 3: Rate of Sickness in SSI

	Count
Increased	90
Decreased	Nil
Same	10
Total	100

Near unanimous response that rate of sickness has increased is being revealed by table 3. RBI data on sickness is no doubt very important source of information but does not provide complete information since RBI data refers to those units, which have raised finance from banks. There are large numbers of SSI units, which do not go to the banking sector for loans. They raise the funds from their own sources, i.e., out of own savings, or borrow from friends and relatives. Reliable information regarding impact of liberalisation & WTO on such units is not available.

Table 4: Percentage of Sickness that can be attributed to WTO Regime

	Count
Significant	40
Insignificant	60
Total	100

Only 40 respondents as per table 4 felt WTO regime responsible for sickness in the SSI sector. While most of

them opined that sickness was always greater in the SSI sector when compared to the large-scale sector because of their inherent weaknesses of less risk bearing capacity, problems of finance, lack of economics of scale, technological backwardness and delayed payments by large industry, respondents also observed that sickness has not increased because of the WTO regime only but most importantly because of wrong management. Even those in the small-scale industries realize that they cannot turn blind eye to changed needs of the customers and they also want to grow and compete with foreign products and tap the export opportunities which the WTO regime has brought with it. But they blame the other bottlenecks more for their failure to cope up. Most of them said that the fault does not lie with the WTO regime (since it was inevitable), but in the way it was being managed. They forwarded certain suggestions also to make the system work well.

Therefore, the hypothesis that the WTO regime is responsible for the increase in the rate of sickness and closure of large number of units within SSI is accepted only partially. The rest of the questions were open ended.

Threats, Opportunities and Suggestions

Responses regarding threats, opportunities and suggestions are reproduced in following tables:

Table 5 A

Sl. No.	Threats in the Area of Frequency*	Responses Frequency*	% age
1.	Toys	95	18.45%
2.	Watches and Clocks	30	5.83%
3.	Packaging Items	70	13.59%
4.	Pharmaceuticals	60	11.65%
5.	Ceramics	80	15.53%
6.	Woven sacks	40	7.77%
7.	Bicycles and their parts	60	11.65%
8.	Electronic items and their components	30	5.83%
9.	Novelties and gift items	50	9.71%
	Total	515	100.00%

* Multiple Responses

Source: Field Survey

As revealed by table 5A & 5B, threats are mainly in the case of toys, packaging items and bicycles and their parts while opportunities exist in software industry followed by auto components and ready-made garments.

Table 5 B

S. No.	Opportunities in the Area of	Responses Frequency*	%age
1.	Gems and jewellery	60	16.67%
2.	Software industry	90	25.00%
3.	Readymade garments	80	22.22%
4.	Chemicals	50	13.89%
5.	Auto components	80	22.22%
	Total	360	100.00%

* Multiple Responses

Source: Field Survey

Table 6A: Suggestions to Government

S. No.	Suggestions	Responses Frequency*	%age
1.	Improve availability of capital (need based rather than security based)	90	22.50%
2.	Single law governing SSI	60	15.00%
3.	Labour law reforms	50	12.50%
4.	Improvement in infrastructure	60	15.00%
5.	Sound information system and training programme	70	17.50%
6.	Reduce import duties on raw materials	40	10.00%
7.	Cluster development	40	10.00%
	Total	400	100.00%

* Multiple Responses

Source: Field Survey

Table 6B: Suggestions to Entrepreneurs

S. No.	Suggestions	Responses Frequency*	%age
1.	Be proactive rather than reactive	60	24.00%
2.	Try to be better-informed	50	20.00%
3.	Concentrate on quality aspect	60	24.00%
4.	Go for consolidation	40	16.00%
5.	Try to enter the supply chain as ancillary	40	16.00%
	Total	250	100.00%

*Multiple Responses

Source: Field Survey

As is revealed by table 6A & 6B, timely and adequate availability of capital and information are quite important

for entrepreneurs, so the government and entrepreneurs should play an active role. The respondents observed, it is the time for consolidation and readjustments.

The study mainly concludes that though awareness about the WTO regime is abysmally low among SSI entrepreneurs, it is an opportunity as well as threat as it has benefited certain industries while harming some others. The WTO regime is responsible for increase in the rate of sickness and closure of large number of SSI units in the country. It is going to be a challenging task for SSI in India to survive and thrive unless timely policy corrections are made.

Implications of WTO Regime on Auto Component Sector

The auto sector can be divided into two segments i.e. vehicle manufacturing and component manufacturing. The auto sector consists of more than 20,000 components, each performing different functions that differ not only functionally but also in terms of the materials they are made of such as plastic components, rubber parts and metal components. A component here refers to all those parts and components that are used in making automobiles, except the chassis and body. The Auto Component Manufacturers Association (ACMA) classifies these components into six categories depending on the broad type of function they serve in an automobile. These include engine parts, electrical parts, drive transmission and steering parts, suspension and braking parts, equipment and others.

Auto Component Sector and SSI

As per the estimates of the Auto Component Manufacturers Association (ACMA), in the auto component sector there are about 400 organised players and 5,000 unorganised players. The unorganised SSI sector is estimated to contribute nearly 23 per cent to the industry's total production. Many of these unorganised units are located in the northern states of Delhi and Haryana. Most of these manufacturers use primitive technologies and buy second hand machinery. Unorganised players are more likely to be involved in the production of low technology products that have lower production complexity such as gaskets, engine valves, pistons and sheet metal parts.

Results of the Study

Problems faced by the entrepreneurs

Entrepreneurs were asked to give order 1, 2, 3 ... and so on, assigning 1 to the most important problem and 2 to the problem considered next in the order. As depicted in table 7, shortage of capital was accorded the highest priority by 70 respondents while 30 respondents gave it the second priority and 10 have given it third priority. Expensive raw material factor was given the highest priority by 40 respondents while 20 respondents rated it to be second priority. Inability to compete with foreign products was not considered to be a problem because the industry is not facing the challenge from imported auto components rather industry is able to export which are increasing.

Table 7: Auto Components (110 units)

	Shortage of Capital	Expensive Raw Material	Power Shortage	Labour Problems	Problems of Inspector Raj	Infrastructure Problems	Inability to Compete with foreign products
I	70	40	0	0	0	0	0
II	30	20	10	0	40	10	0
III	10	10	20	30	20	20	0
IV	–	20	30	20	10	30	0
V	–	20	30	20	30	10	0
VI	–	–	20	20	10	40	20
VII	–	–	–	–	20	–	90

Source: Field Survey

Awareness status

It was observed by the respondents that wide information gaps exist and the SSIs units are not well informed. Government mechanism is lacking in this regard and one wonders what purpose is being served by various government agencies, which survive in the name of promoting small industry. The Government has schemes for obtaining ISO 9000 and ISO 14000 for SSI units but most of the units are not aware of those schemes. Table 8 reveals responses on the awareness status of the sample units.

Table 8: Awareness Status

	Yes	No	Total
World Trade Organization	60 (55%)	50 (45%)	110 (100%)
Removal of Quantitative Restrictions	50 (45%)	60 (55%)	110 (100%)
Various agreements under WTO	30 (27%)	80 (73%)	110 (100%)
ISO 9000 (Quality Management Systems)	60 (55%)	50 (45%)	110 (100%)
ISO 14000 (Environment Management Systems)	50 (45%)	60 (55%)	110 (100%)

Source: Field Survey

Issue of Dereservation

The dereservation spree is also a consequence of the WTO regime. 39 items were de-reserved from 1997 to 2001 and 51 more items were dereserved in 2002-03. In the budget of 2004-05 also the dereservation of 85 items was announced. Therefore, it becomes imperative to study the impact of such policy measures on the industry.

In order to study the mindset and impact of government policy measures, a question was included in the questionnaire regarding the initiation of dereservation and related issues. Majority of the owners of auto-component units were not aware of the existence of reservation for SSI in the area of auto components. That was quite surprising information. Preference for purchase from SSI by the government sector was also not known to them.

Performance of the auto component industry in the SSI sector was analysed in terms of volume of sales, profit margins and export trends as shown in Table 9.

Table 9: Auto Component Units

Volume of Sales (Domestic & Foreign)								
	2000-01 Units			2001-02 Units			2002-03 Units	
Increased	65	(59%)		60	(54.5%)		40	(36.3%)
Decreased	10	(9.1%)		20	(18.1%)		30	(27.2%)
No change	35	(31.8%)		30	(27.2%)		40	(36.3%)
Total	110	(100%)		110	(100%)		110	(100%)
Profit Margins								
	2000-01 Units			2001-02 Units			2002-03 Units	
Increased	50	(45.4%)		40	(36.3%)		30	(27.2%)
Decreased	35	(31.8%)		40	(36.3%)		70	(63.6%)
No change	25	(22.7%)		30	(27.2%)		10	(9.1%)
Total	110	(100%)		110	(100%)		110	(100%)
Volume of Exports								
	2000-01 Units			2001-02 Units			2002-03 Units	
Increased	40	(80%)		45	(75%)		40	(66.6%)
Decreased	10	(20%)		15	(25%)		0	–
No change	0	–		0	–		20	(33.3%)
Total	50	(100%)		60	(100%)		60	(100%)

Note: Percentage totals may not agree because of rounding off the figures.

Time Series Analysis

While analyzing volume of sales, it is observed that only a few units reported a decrease in volume of sales while profit margin declined in quite a good number of cases. That shows the increase in competition and thereby in spite of sales volume decrease, profit margins are slackening. On analyzing the exports scenario, it has been observed that the situation has not deteriorated (considering the total number of units which reported an increase and no change in volume of exports).

Cross-Sectional Analysis

As per the suggestions by ACMA officials, a question pertaining to the nature of units (whether an ancillary to OEM/a part of supply chain or catering to OEM as well as replacement market or replacement/after market) was included in the questionnaire. Therefore, in order to assess impact in right perspective units reporting increase, decrease or no change in various parameters of performance were further classified according to their nature as is shown in the following table 10.

Table 10: Volume of Exports

	2000-01			2001-02			2002-03		
	(a)	(a+r)	(r)	(a)	(a+r)	(r)	(a)	(a+r)	(r)
Increased	62.5%	–	33%	87.5%	–	22%	87.5%	–	11%
Decreased	–	40%	–	–	40%	11%	–	–	–
No change	–	–	–	–	–	–	–	40%	22%

Source: Data compiled from field survey.

Notes:

1. Out of 110 units, 40 are ancillary, 25 are replacement + ancillary and 45 are replacement units.
2. (a) stands for ancillary, (a+r) stands for ancillary + replacement, (r) stands for replacement
3. Category wise percentage of units, which reported, increased, decreased or no change with respect to previous year.
4. Percentage is calculated for exporting units out of total number of units for volume of exports i.e. 50 units in 2000-2001 and 60 units each in 2001-02, 2002-03.
5. The above table regarding volume of exports worked out on the basis of following data:

	2000-01Units			2001-02 Units			2002-03 Units		
	(a)	(a+r)	(r)	(a)	(a+r)	(r)	(a)	(a+r)	(r)
Increased	25	–	15	35	–	10	35	–	5
Decreased	–	10	–	–	10	5	–	–	–
No change	–	–	–	–	–	–	–	10	10

Following are some important facts, which came to light on further analysis:

1. *Performance of units in terms of parameters such as volume of sales, and profit* margins was

quantified by assigning codes 3 to increase, 2 to no change and 1 to decrease. Mean scores were calculated for different units on the basis of their nature.

Table 11: Auto Component Units

Mean Scores (2002-03)

	Nature of Units	Volume of Sales	Profit Margins
(a)	2.50 (40)	2.75 (40)	3.00 (35)
(a+r)	2.80 (25)	1.00 (25)	2.00 (10)
(r)	1.33 (45)	1.00 (45)	2.33 (15)

Source: Data compiled from field survey.

Note: Figures in parenthesis indicate number of units

Figures in tables 10 & 11 clearly show that performance of ancillary is better than the performance of units catering to replacement or after market. The reason is not far to look at: all these units in response to questions in the questionnaire, specified lack of demand to be their main problem.

2. *Performance in export market:* In 2002-03 out of 110 units, 60 were engaged in exports. Only 15 out of 45 replacement units were engaged in exports of which only five reported an increase in exports. According to industry sources the proportionate share of after-market is shrinking in the foreign market also. Some units are able to sell in the after-market in the Middle East and Africa. 35 ancillaries reported increase in exports, which is indicative of the fact that ancillaries have gained in tapping foreign market.

3. *Visualisation regarding future trends:* It hints at the fact that ancillaries hope to perform better than replacement units. Some ancillaries are buoyant, confident and making investments. But ancillaries are also worried to come up to the expectations of OEMs and foreign clients.

Has the SSI segment of Auto Component Industry been able to benefit from the WTO regime?

The SSI segment, which is ancillary to vehicle manufacturers, has no doubt benefited from the WTO regime, as exports (components as well as vehicles), have risen but the contribution of replacement component to export market as well as the local market has declined. With improvement in quality of vehicles, domestic replacement market has faced a crunch, thereby making survival difficult for small units within SSIs. Share of the replacement market in the export market is also declining. Therefore, on the basis of analysis of primary and secondary data and inputs from interviews, it will be proper to conclude that SSI segment of auto component industry is able to benefit from WTO regime through increased exports.

Hypothesis to be tested: The impact of the WTO regime has not been uniform across size.

Methodology Adopted

(a) Units interviewed are classified according to capital employed (which signifies the size of units).

(b) Since qualitative information could be collected it was codified by assigning codes, 3 to increased, 2 to no change and 1 to decrease for various parameters such as volume of sales, profit margins and volume of exports.

(c) Mean scores were calculated using statistical package for social sciences (SPSS).

The following table reveals the results:

Table 12: Mean Scores (2002-03)

Capital Employed (Rs. in lakhs)	Sales Volume	Profit Margin	Volume of Export
0 - 25	1.86 (70)	1.01 (70)	2.20 (25)
25 - 50	2.00 (20)	2.50 (20)	3.00 (15)
75 - 100	3.00 (20)	3.00 (20)	3.00 (20)

Source: Data compiled from field survey, codified and then processed using SPSS.

Note: Figures in parenthesis indicate number of units.

On comparing the mean scores it can be observed that large sized units within the small-scale sector are able to perform better and the hypothesis that the impact of the WTO regime has not been uniform across size is accepted.

To conclude we may say that there is hardly any future for tiny units in this sector. Small units, which are not a part of the supply chain, also fear extinction. And relatively large units within the small scale sector can continue to perform well if they pay attention to realities and be proactive rather than be reactive to the emerging situations.

Observations and recommendations

Following are some the observations and recommendations based on the responses:

1. Units which are ancillaries, supplying directly or

indirectly to auto manufacturers are performing well and it is hoped that many of them will be able to survive provided the operational challenges such as quality, scale, logistics and the like are met by them.

2. The study indicates that only those who are able to integrate them well into the supply chain are performing well. But for such units also the future will be bleak if they are not able to innovate and sustain themselves in the supply chain. For this they will need consolidation and a huge investment of funds and thereby are coming out of the small scale ambit.
3. It has been observed that there seems to be negative implications of the WTO regime on the auto component sector because the sector was sufficiently protected through the means of Local Content Programme, Dividend Balancing and entering into Memorandum of Understanding with MNCs.
4. Industry is facing problem of expensive raw material. Tariff duty on raw material (such as steel, aluminium, copper and plastics) is high. Local raw material manufacturers have formed a cartel and by practicing monopoly powers they are exploiting their users
5. India has enough potential for exports in auto component sector. Table 13 throws light on the fact that Indian auto component industry has a future but at the same time it has a long road to go.

Table 13: US Component Imports

	Mexico	Brazil	China	Thailand	India
1998	14,574	1,082	863	309	99
1999	16,814	1,147	1,041	374	117
2000	18,791	1,086	1,368	362	150
2001	18,402	824	1,483	380	141
2002	20,397	1,137	1,884	516	177

Source: US Census, Bureau Foreign Trade Statistics, Figures in $ million

6. India's strengths over China lie in its educated and skilled work force that have strong engineering skills and are well conversant in English. However, inadequate and poor quality infrastructure, complicated tax structures, inflexible labour laws, inconsistent policies across states, complex procedures and government regulations put India at a disadvantage as compared to China as a manufacturing centre. The Indian auto industry needs to capitalize on the high design and engineering capabilities, which are available at competitive rates and needs to concentrate on building the "Made in India" brand. The government needs to improve infrastructure, reduce excise and import duties, and introduce flexible labour laws to improve industry competitiveness.

To conclude, manufacturers/suppliers should introduce strict quality control measures to protect against defects in the design or manufacturing of their products. They should be careful with the terms of contract, in developing product warnings and promotional materials. In order to mitigate risk and provide additional protection against liability they need to obtain product liability insurance.

Implications of the WTO Regime on Plastic Processing Sector

Challenges posed by the WTO on Plastic Processing Sector are principally on three fronts:

i. Removal of QRs

ii. Tariff levels

iii. Limitation imposed by the WTO on the grant of subsidies.

Indirect implications are de-reservation of certain plastic products from the list of items reserved for exclusive manufacturing by SSI. The purchase preference by government sector for SSI is also being withdrawn.

Results of the Study

Problems Faced By the Entrepreneurs

Entrepreneurs were asked to give order 1, 2, 3 ... and so on, assigning 1 to the most important problem and 2 and subsequent numbers to the problem considered next in the order. As depicted in table 20, shortage of capital was accorded the highest priority by 60 respondents while 30 respondents gave it the second priority and 5 given it third priority.

Expensive raw material factor was given the highest priority by 35 respondents while 30 respondents rated it to be second priority. Due to frequent increase in price of raw materials, the plastic manufacturers are calling for a price regulatory mechanism. One reason for the high price of plastic raw material in the country may be the monopoly of Reliance on the manufacture of polymers in the country. Reliance sets the monopolistic price and others follow suit. The price of polymers manufactured

in Korea or Kuwait is cheaper (between $ 600 and $ 900 per tonne) as compared to India where it is priced equivalent to $1200. Another reason may be the high import duty on polymer. One of the important reasons why the domestic plastic manufacturer is unable to compete with China is because of the high cost of polymers. That is why government is giving huge protection to the domestic manufacturers of polymers.

Labour is not considered to be much of a problem. On the other hand the inability to compete with foreign products was considered to be a problem because the industry is facing a challenge from imported products. Inability to compete with foreign products was given second priority by 35 respondents and third priority by 35 respondents. On further analysis of responses it became clear that those processing units, which produce woven sacks, gift items, novelties, and packaging items mainly, marked this factor to be troubling them. According to industry sources many moulded plastic units have given up manufacturing. Plastic moulded products such as pens, plastic woven fabric such as packing material and cigarette lighter made of plastic are being imported. China and Nepal have a trade agreement and have free movement of goods across the border. India has a free treaty with Nepal and made in China goods are being passed off here as made in Nepal goods.

The respondents specifically mentioned some more problems including that the banks do not give loan without collateral, red-tapism and bureaucratic delays; high interest rate; lack of awareness about various schemes, etc. The following table amply clears these facts:

Table 14: Problems

	Shortage of Capital	Expensive Raw Material	Power Shortage	Labour Problems	Problems of Inspector Raj	Infrastructure Problems	Inability to Compete with foreign products
I	60	35	0	0	0	0	0
II	30	30	0	0	0	0	35
III	5	25	10	0	20	0	35
IV	–	5	20	0	20	25	25
V	–	–	30	10	25	30	–
VI	–	–	30	5	20	40	–
VII	–	–	5	80	10	–	–

Source: Field Survey

It is observed that only bigger units among the SSI ones were able to tap the benefits of the schemes of the government, may be because of their connections or sound information network. As observed by the office bearers of the All India Federation of Plastic Industries, the price is not only high but also it is hiked frequently. The Association is pursuing major polymer producers for keeping stability in polymer prices by keeping the same fixed for a quarter at best or at least for a month. Stability in polymer prices is essential so that downstream processing industry can properly plan its production and marketing activities. The following table reveals frequent hike in the price:

Table 15: Hike in Price

Date	RIL Price Per Ton
1.1.2002	Rs. 37,237/-
1.2.2002	Rs. 39,556/-
15.2.2002	Rs. 40,716/-
1.3.2002	Rs. 43,036/-
16.3.2002	Rs. 45,356/-

Awareness Status

Awareness level is found to be quite low especially about the nitty-gritty's of WTO regime as is revealed by following table:

Table 16: Awareness Status

	Yes	No	Total
World Trade Organization	60 (63%)	35 (37%)	95 (100%)
Removal of Quantitative Restrictions	50 (53%)	45 (47%)	95 (100%)
Various agreements under WTO	30 (32%)	65 (68%)	95 (100%)
ISO 9000 (Quality Management Systems)^	40 (42%)	55 (58%)	95 (100%)
ISO 14000 (Environment Mgt. Systems)	30 (32%)	65 (68%)	95 (100%)

Source: Field Survey

Performance of Plastic Processing Units

Performance of Plastic Processing Units was analysed in terms of volume of sales, profit margins and export trends as shown in Table 17.

Number of units reporting decrease in volume of sales and profit margins has increased from year to year. It is observed that volume of exports increased in a few cases, which was so only in case of larger units within SSI.

Table 17: Plastic Processing Units

Volume of Sales (Domestic & Foreign)						
	2000-01 Units		2001-02 Units		2002-03 Units	
Increased	50	(52.6%)	45	(47.3%)	40	(42.1%)
Decreased	25	(26.3%)	30	(31.5%)	40	(42.1%)
No change	20	(21%)	20	(21%)	15	(15.7%)
Total	95	(100%)	95	(100%)	95	(100%)
Profit Margins						
	2000-01 Units		2001-02 Units		2002-03 Units	
Increased	35	(36.8%)	30	(31.5%)	25	(26.3%)
Decreased	45	(47.3%)	50	(52.6%)	60	(63.1%)
No change	15	(15.7%)	15	(15.7%)	10	(10.5)
Total	95	(100%)	95	(100%)	95	(100%)
Volume of Exports						
	2000-01 Units		2001-02 Units		2002-03 Units	
Increased	15	(42.8%)	15	(42.8%)	20	(57.1%)
Decreased	15	(42.8%)	20	(57.1%)	10	(28.5%)
No change	5	(14.2%)	–	–	5	(14.2%)
Total	35	(100%)	35	(100%)	35	(100%)

Note: 1. Figures in parenthesis indicate percentages.
2. Percentage totals may not agree because of rounding off the figures.

Would the situation of Plastic Processing Industry be any different had there been no WTO?

The answer is in the positive because imports have captured the market, which was earlier being controlled by small plastic processing units. Therefore sales became sluggish in a few cases and those who stated an inability to compete with foreign products as a major problem, belonged to this category. Some of the units (comparatively larger) are able to sustain their performance because of increased demand due to booming construction activity in the country and increase demand from healthcare industry and auto industry. A few of them are able to tap export opportunities also. It can be concluded that imports have hurt the Indian plastic processing industry more than its own inherent problems.

Hypothesis to be Tested

The impact of WTO regime has not been uniform for the plastic processing industry across size.

Methodology Used

The following methodology was adopted:

i. Units interviewed are classified according to capital employed (which signifies the size of units).

ii. Since qualitative information could be collected so it was codified by assigning codes, 3 to increased, 2 to no change and 1 to decreased for various parameters such as volume of sales, profit margins and volume of exports.

iii. Mean scores were calculated using Statistical Package for Social Sciences (SPSS).

Results are produced in the following table:

Table 18: Mean Scores (2002-03)

Capital employed (Rs. in lakhs)	Sales volume		Profit margin		Volume of export	
0 - 25	1.42	(60)	1.17	(60)	1.33	(15)
25 - 50	3.00	(20)	2.25	(20)	3.00	(10)
50 - 75	3.00	(5)	2.00	(5)	–	–
75 - 100	3.00	(10)	3.00	(10)	3.00	(10)

Source: Data compiled from field survey, codified and then processed using SPSS.

Note: Figures in parenthesis indicate number of units.

On comparing the mean scores, it can be concluded that smaller units within the SSI sector have been hurt more. Therefore, the hypothesis that the impact of WTO regime has not been uniform across size and imports have hurt the relatively smaller units within the SSI sector more is accepted.

Some Observations

The following observations are based on the responses:

China has certain advantages as compared to India. In China, there is no custom duty imposed on raw materials and also there is no excise duty either. Further, in China electricity is cheap and China is able to import machines from Germany without any import duty. Also, in China there are no stringent labour laws.

Custom duty on polymer, which is required by plastic processing units, is kept equal to duty on finished products thereby harming the interest of SSI in more than one way. If custom duty on polymer is reduced, the indigenous manufacturers will be forced to keep stability in prices as well as to fix reasonable prices at near international price level. It is noteworthy here that very low rate of custom duty is applicable on the inputs like

crude, ethylene, naptha meant for the major polymer manufacturers.

In a nutshell it can be said that imports of plastic goods of concern to SSI have registered a 32 per cent growth per annum. These imports have hurt the Indian plastic processing industry badly. Although some larger players within SSI are able to sustain their performance, yet on the whole this sector has suffered because of the WTO regime. To minimise their suffering anomalies in duty structure should be immediately removed. The impact of WTO has not been found to be uniform across size. It is found that relatively larger units within SSI were able to face WTO regime in a better way as reflected by comparison of mean score in the study for the year 2002-03.

Conclusion

Small Scale Industries (SSI) play a vital role in the process of growth in developing countries like India. These are considered to be the powerful instruments of economic decentralization, employment generation and dispersal of industries over different regions. This sectoral study mainly concludes that though awareness regarding the WTO regime is abysmally low among SSI entrepreneurs, it is an opportunity as well as threat as it has benefited certain sectors while harmed some others. The WTO regime is responsible for increase in the rate of sickness and closure of large number of SSI units in the country. It is going to be a challenging task for SSI in India to survive and thrive unless timely policy corrections are made. Benefit of opening up of export avenues shall have to be tapped by adequate and proper training system so that the information gaps get vanished.

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