A

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ON

INDIAN MANUFACTURING SCENARIO

Submitted in partial fulfilment of the requirement for award of degree in Bachelor of Engineering Of

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This is to certify that the lecture entitled

INDIAN MANUFACTURING SCENARIO

(06ME86)

Has been delivered by
CHETHAN R REDDY (1NH07ME010)

The student of 8th semester B.E (Mechanical Engineering) under our supervision and guidance in partial fulfilment of the requirement for the award of degree of Bachelor of Engineering (Mechanical Branch) of Visvesvaraya Technological University, during the academic year 2010-2011.

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ABSTRACT

Manufacturing industry is the engine of economic growth of a nation. It includes all activities in product life, starting from customer inputs for concept design, through conversion of materials and ending with product disposal. These activities provide gainful employment, create the products required to maintain and improve the standard of living and generate the wealth required for future development.

India can and will transform itself into a developed nation through the growth of its manufacturing industry, but this must be achieved in a *responsible and sustainable* manner, creating a role model for other developing nations. Conventional prescriptions emphasizing increased technology transfers, infrastructure projects, tax incentives and R&D spending are not sufficient to ensure manufacturing competitiveness – continuous improvement in price, quality and response. We therefore need a comprehensive *vision*, long- term *mission* and novel *policies* for sustainable growth of the manufacturing industry, evolved after a study of the past, present and future factors.

The history and geography of manufacturing reveals the influence of waves of technology, local resources and conditions existing in different countries at different periods. We also note that ancient India gave science and engineering to the world and medieval India was the leader in manufacture and exports of textile and metal products. At present, however, with less than 1% share of global trade and a poor rank in terms of competitiveness, India has to move aggressively to catch up with other nations.

The future manufacturing industry will be driven by global cooperation and intellectual property rights. Technological drivers include artificial intelligence, green materials and direct manufacturing processes. To ride

these waves, new vehicles will be needed: bionics, reverse engineering, continuous innovation, knowledge management and product life-cycle engineering. These will lead to entirely new products and processes.

The vision is to *create and regenerate all types of wealth* – material, natural, intellectual and cultural –by encouraging and supporting appropriate manufacturing activities that respect nature and maintain a balance among various resources. This can be achieved through a mission to identify, train, deploy and support *manufacturing leaders* – individuals as well as firms. The policies to achieve these are presented as the inter faces between the Government, academia and industry.

The *Government and academia* ought to work together to create 'respect for manufacturing' and a suitable environment for manufacturing knowledge workers (seekers, keepers and users). Discovery of ancient knowledge from scriptures as well as creation of new knowledge through science and technology has to be promoted. Government and academia also need to work closely with the media, to reinforce the positive image of manufacturing sector, create awareness about present challenges and future technologies, and bring the leaders into limelight so as to inspire others.

The *academia and industry* should work together to identify the leaders and create innovative ideas for further exploration. They need to set up joint innovation centres, mutual exchange chairs (industrialist teaches in university; professor conducts research in industry), and compulsory internship for engineering students in industry. Industry should create exciting jobs for such students. Financial rewards must be made equivalent to those in other professions for a similarly qualified per son to attract and retain talent of high calibre to manufacturing.

The *industry and Government* bodies together need to create a favourable environment for entrepreneurs to commercialize new product/process ideas, especially in high growth or strategic areas. Scientists in Government research labs may evaluate project proposals forwarded by financial institutions, assist in pilot production and further guide by joining the board of directors of manufacturing firms. The cooperative model, very successful in diary sector, should be applied to manufacturing clusters to promote common research, training and marketing, and benefit from economies of scale. They should be allowed to decide and create the local infrastructure best suited to their needs in partnership with the Government.

India has a natural advantage in two areas because of local availability of raw materials, suitable manpower and a large domestic as well as export market: (1) *agri-centric labour - intensive* products like convenience and health foods, and (2) *metal-based engineering - intensive* products like automotive castings.

The global competence and confidence gained by Indians in *Information Technology* must be used for eliminating, automating, speeding and value addition in tasks related to design, production and supply chain management. Major bottlenecks – lack of awareness, inadequate technical support and high cost – can be overcome through training programs, indigenous development of I T solutions and (temporary) financial incentives. This will provide an additional competitive edge.

The document evolved through a series of brain storming sessions by an interdisciplinary team of people, then supporting the logic with references and data. Still, this work is just a tiny thread of thought processes, and must be woven with those from others. We sincerely hope that students, teachers, researchers, practicing engineers and policy-makers will find some interesting nugget to explore further.

CONTENTS

MANUFACTURING FOR WEALTH CREATION

In this section, we first define manufacturing and classify different types of manufacturing. We will also study its relation with other sectors of economy and review its role in national development, including creation of different types of wealth.

DEFINING MANUFACTURING

Manufacturing can be defined as physical and/or chemical transformation of materials into products on a large scale using machinery or capital equipment, in contrast to production of handmade goods for personal use. The products provide utility or satisfaction to human/living beings. They may take the form of final consumption goods, semi- finished goods (parts and raw materials) or capital goods (used for making final products). Associated activities such as blending of materials, assembly of components, and finishing (painting, heat- treating, packaging, etc.) are also treated as part of manufacturing. Let us examine this definition further and see the extent to which it will be meaningful in future.

From an engineering point of view, one can conceive of two types of products: discrete products (e.g., chair and phone) and continuous products (e.g., sugar and paper). The manufacture of discrete products includes the processing of materials, fabrication of components and sub-assemblies (intermediate products), and the assembly of final products. There is no such assembly activity in continuous products, which involve a series of conversions star ting from raw materials. Some products, *e.g.*, a bottle of pills, combine both types of products: continuous, followed by discrete. New technologies such as free form fabrication are gradually blurring this distinction. In future, continuous processes may manufacture many discrete products.

The actual act of production (conversion of materials into usable form) is getting more and more efficient and automated, especially in developed countries. This is associated with reduced costs, lead – time and labour. The focus and investment of resources (finance and employment) is shifting to other activities in product development as well as services. For example, considerably larger time is spent in designing a modern aircraft and managing its supply chain logistics than in its manufacture.

The traditional definition of manufacturing associates it with economies of scale, implying standard parts. This is owing to the high cost of research and development, tooling and production facilities for a specific product, which need to be amortized over a large number. Thus, exclusive and custom-made products are expected to have high value and cost. This gap is asymptotically reducing to zero because of flexible and direct manufacturing systems. Mass manufacturing is giving way to mass customization.

An original equipment manufacturer (OEM) is understood to be a place where labour, materials and machines converge to produce finished products. The term OEM is not suitable for continuous products and will not be used hereafter. In contrast, supplier firms are understood to be those, which create semi- finished products, components or materials for use by the main manufacturers. First- tier firms supply to the final product manufacturer, second- tier firms supply to the first- tier firms, and so on.

The manufacturing activities (main as well as supplier s) require an array of support and service activities. The vital ones include energy supply, equipment maintenance, transportation (for raw materials, semi- finished and finished products), marketing (including customer research and advertisement), reselling (to an intermediate or final customer), finance (borrowing, accounting, saving), human resource management (from hiring to firing), information & knowledge management and legal (covering virtually every activity). In the past, firms tended to perform all the activities themselves – referred to as vertical integration – with handsome returns and growth. T he increasing complexity of support and service activities (beyond a critical point) swung the trend in the opposite direction. Manufacturing firms started focusing on their 'core' competence and activity, outsourcing 'non-core' activities to specialized firms. However, the steep growth and fall of service firms, especially those related to information technology, may lead to other patterns in future.

PRODUCT LIFE AND CYCLE

The traditional definition of manufacturing focuses only on the act of production: starting from raw materials, conversion through a number of stages, and ending with assembly and testing. A more comprehensive definition includes all activities in product life, starting from customer inputs for concept design, and ending with product disposal (including repair and recycling). Let us look at these briefly.

The first step is the expression of a need that could be actual as in the case of 'market pull' products (clothes' ironing machine), or perceived as in the case of technology-push products (virtual reality systems). This is converted to product requirements using techniques such as Quality Function Deployment by market researchers. Then industrial designers take over and generate concept designs for shape and function. The engineering design team analyzes the selected concept to finalize the material, geometry and quality specifications. Virtual and real prototypes are fabricated and tested to validate the design. This is followed by the development of product- specific tooling, process plans and manufacturing facilities, if necessary. Trial productions are carried out to fine- tune the process parameters and regular production starts. This involves manufacture of components, joining, assembly, finishing, inspection and packaging. T he product is shipped to intermediaries and eventually to the customer.

This is however, only the beginning of the real life of the product. The product is used for its intended (and sometimes unintended) purposes, usually consuming energy. I t may require timely maintenance and sometimes unexpected repair work. Some of its parts may be replaced, because of functional or aesthetic reasons. The ownership may change. Finally, when the product has outlived its life because it cannot function anymore or because significantly improved new products are available, and then it is discarded. I t may be disassembled and the components are reused (in another product of the same type), recycled (another application) or simply dumped. I n general, the real cost of the product (including its energy consumption, maintenance, upgrading and impact on environment) may be several orders of magnitude than its purchase price.

CLASSIFICATION SYSTEM

The traditional classification system is based on the specializations of firms. The list has been standardized and adopted by various bodies, such as United Nations and European Union, to facilitate international comparison. The list of manufacturing sectors includes food, textile, chemical, automobiles, electrical machinery, telecommunication, etc.

(See Table 1.1)

The industries dominating at the time of classification exert a significant influence compared to nascent industries, which are tiny but have a great potential for growth. Thus, it is quite possible that in future, the size of tobacco industry may gradually diminish (owing to government regulations and social norms) and merge in the food products category. On the other hand electrical, electronic and computing equipment and their sub categories (say, food processing equipment) may rapidly grow to claim separate categories.

Table 1.1 – Manufacturing Sector

Code	Products
15	Food products and beverages
16	Tobacco products
17	Textiles
18	Textile products including wearing apparel
19	Leather , leather products and footwear
20	Wood, wood products
21	Pulp, paper and paper products
22	Printing and publishing
23	Coke and petroleum products
24	Chemicals and chemical products (including pharmaceutical)
25	Rubber and plastics products
26	Other non-metallic mineral products
27	Basic metals (ferrous and non- ferrous)
28	Fabricated metal products , except machinery and equipment
29	Non-electrical machinery and equipment
30	Office, accounting and computing machinery
31	Electrical machinery and apparatus
32	Radio, television and communication equipment
33	Medical, precision and optical equipment
34	Motor vehicles
35	Marine vessels , aircraft, spacecraft and railroad
36	Furniture products
37	Recycling

Source: STAN Industry List, www.oecd.org

The above classification assumes vertical integration in any sector. In reality, any given sector requires a high level of specialization for various activities such as product design, production equipment development, process planning and marketing. On the other hand, there is increasing similarity between the methodologies and technologies used for such specialized activities even across sectors.

For example, computer -aided tools (such as virtual reality visualization and finite element analysis) and market research tools (such as quality function deployment) can be used for wood products, plastics products and metal products, which span different manufacturing sectors. This calls for a different classification system based on specialization in terms of activity (or process) rather than the product.

Another development is that service firms are talking about their products (such as a new insurance scheme), and manufacturing firms are offering their products as services. An example of the latter is that an end-user may purchase a computer or a photocopier as a service instead of as a product. The manufacturer delivers the machine, maintains it (including upgrading) and eventually takes it away (buy back options) when the user wants it no more. I n future, all products and services may be lumped together as services. A particular service may comprise a series of steps involving products and services.

Depending on the needs of the end-user, the products and services can be classified as (a) basic needs: required for maintaining life with bare necessities such as food, apparel, shelter, commuting and communication; (b) comforts: to improve the standard of living, including automatic food processing equipment, refrigerators, air conditioners, television, music systems, etc.; and (c) luxuries: to improve the quality of life, such as decorative items.

The products may also be classified based on the type of resources and the level of technology involved: (a) labour - intensive natural products, such as minerals and farm produce, (b) skill- intensive low technology products such as shoes and textiles, (c) material- intensive intermediate technology products such as automobile components, and (d) high capital and technology intensive products such as robots.

Another classification can be based on the type of user (say, by age and gender) and level of user (individual, family and activity group). A third system can be based on the number of levels from the end-user. Thus fertilizer manufacturers cater to the needs of farmers, who in turn produce agricultural products, which are in turn processed by food processing firms into the final product, consumed by end-users.

The above developments: specialized activities within any sector, product complexity and level of technology involved, and user –centric solutions (products or services) may lead to entirely new systems of industry classification in future.

RELATIONSHIP WITH OTHER SECTORS

Economic activities can also be viewed as primary, secondary and tertiary. Primary activities include cultivation and exploitation of natural resources; *i.e.*, agriculture, forestry, fishing, livestock, mining, quarrying and oil-exploration. The secondary sector essentially constitutes manufacturing activities, which take the output of primary industries and convert them to consumer and capital goods. Finally, tertiary sector constitutes service activities of the economy (T able 1.2). Historical patterns of economic development indicate that in the initial stages of development of a country, a large proportion of national income is derived from the primary sector and also the labour force is heavily dependent on the primary sector. As an economy moves on to the industrialization process (due to increased productivity in primary sector), manufacturing sector starts growing and the labour released from primary sector is absorbed into manufacturing or secondary sector. Concomitant to this, the contribution of manufacturing sector to national income also increases. When the manufacturing sector develops and is on its way to maturity, it generates demand for services and in the final stage of development it is the service sector that becomes a major contributor to both national income and employment. Thus, the development process first satisfies the commodity needs of human beings and it is only when these needs are met, the service needs start emanating.

Table 1.2 – Sectoral classification

Code	Services
01-05	Agriculture, hunting, forestry and fishing
10-14	Mining and quarrying
15-37	Manufacturing
40-41	Electricity, gas and water supply
45	Construction
50-52	Wholesale and retail trade
55	Restaurants and hotels
60-63	Transport and storage
64	Post and telecommunication
65-67	Financial intermediation and insurance
70-74	Real estate, renting and business services
75	Public administration and defense
80	Education
85	Health and social work
90-93	Other community, social and personal services

Source: STAN Industry List, www.oecd.org

India's development pattern has differed from the historically observed development pattern (see Table 1.3). In India, though service sector has become the major contributor to national income (due to the availability of highly skilled personnel and relative scarcity of capital), a significant proportion of labour force has still not found jobs in secondary and tertiary sectors and therefore has to depend on primary sector. In 1999-2000, Out of about 400 million workers employed in Indian economy, 60% were employed in agricultural sector, 12% in manufacturing sector and 28% in service sector [Economic Survey, 2001-02].

The high proportion of population engaged in a single sector and its contribution to national income has aroused concern in several quarters. A glance at Indian (post-independence) history reveals that planning process accorded high priority to the industrial sector and currently the emphasis is on the service sector. Attention to agricultural sector was paid, as and when it became a dire necessity. While we have been getting our selves organized in primary production, the technology changed at rapid pace, and all of a sudden we found ourselves taking a leap to the tertiary sector, stealing a few decades from the manufacturing sector.

Table 1.3: Sectoral contribution to GDP (percentage share)

Sector	1951-52 to 1955-56	1985-86 to 1989-90	1999-2000
1. Agriculture	54.9	32.8	23.2
2. Manufacturing	11.9	20.0	17.1
2.1 Registered mfg	5.5	12.1	11.3
2.2 Unregistered mfg	6.4	7.9	5.8
3 Residual (services)	33.2	47.2	59.7

Source: http://planningcommission.nic.in, National Accounts Statistics, CSO.

For the development of a nation, all sector s have to move in tandem with each other. One could argue that, we are self sufficient in agriculture and are making good money in service sector and what is wrong about it? If Swiss can live on watches, why can't we on IT enabled services? To answer this question we need to look how the three sectors interact with each other. Agriculture is becoming more and more technology oriented and as the level of prosperity of our country increases, the human intensiveness is becoming increasingly costlier. For the agriculture to grow, we need more value addition. Sugarcane production needs to be complemented by sugar factories. Sunflower export alone does not pay enough, the population and its expectations have increased: we need sunflower oil extractors, and so forth. Any improvement in the efficiency of primary sector frees a portion of human capital hither to dependent on it. For such capital to be involved in productivity of the nation, there is a need for creation of opportunities, which can be found in higher levels of industries. Service sector is a consumer oriented sector and relies heavily on the domestic or foreign demand to sustain itself. A big portion of domestic demand consists mainly from those by urban middle to upper class, which is only a small portion of India and hence, growth of service sector needs to support rather than be regarded as a substitute for Indian manufacturing industry. Service sector breeds on robust primary and secondary sector for any economy that underlines the importance of manufacturing industry. An estimated 70% of service sector worldwide depends on the manufacturing sector.

DEVELOPMENT AND VARIOUS FORMS OF WEALTH

Before we explore the relationship between manufacturing activities and material wealth creation, let us examine the definition of wealth. The notion of wealth as proposed by Adam Smith (1756), widely accepted until recently, encompasses only a part of material wealth in the form of goods. The ultimate goal of wealth ensuring the prosperity and well being of current as well as future generations – is often clouded by over -emphasis on material wealth, often at the cost of other forms of wealth. Material prosperity and wealth cannot provide solutions to human problems and in fact, these may pose a threat to the very survival of human beings in the long run. In view of this, the concept of sustainable development has gained currency over material prosperity. Sustainable development is defined as ensuring a better quality of life for everyone, now and for generations to come. It implies meeting the needs of the present without compromising the ability of future generations to meet their own needs. Key elements include effective protection of the environment and maintenance of high and s table levels of economic growth and employment. In a similar vein, the Endogenous Growth theory postulates link between economic growth (material wealth) and human capital, technology and physical capital as inputs in the growth process. There is an obvious need to evolve a better perception of development process (outcome), which should encompass the links between material, natural, intellectual and cultural wealth (inputs). Material wealth is the most visible form of wealth and can be measured in terms of the current assets and future purchasing capacity. On the other hand, natural wealth has to be converted into material wealth through manufacturing activity. It is here that the conflict and imbalance between the material wealth and preservation of natural wealth becomes the focal problem in developmental process. Intellectual wealth or human capital has to be embodied into manufacturing activities for income and material wealth generation. Finally, cultural wealth provides the foundation and environment to create and sustain intellectual and other forms of wealth.

All types of wealth are complementary to each other and every nation must strive to achieve a balance among them. Nations with imbalance and disproportionality in different forms of wealth may find it difficult to survive in the long run, both individually and collectively. Due to complementarity (or imperfect substitutability) of various forms of wealth, nations that are materially rich and culturally poor, or naturally rich but intellectually poor may find it difficult to progress with the help of fair and democratic means. Let us look at these four types of wealth in some more detail, in particular, the factors that influence their generation and use.

MATERIAL WEALTH

Material wealth is related mainly to real income generation both at present and in future. Another characteristic of material wealth is that it is produced by human effort. In this form of wealth, therefore, we include the stock of capital, infrastructure, commodities produced earlier and of course the real national income currently produced. The stock of material wealth is important as it determines a nation's purchasing and borrowing power in a globalized world.

The public and private infrastructure is the most visible form of material wealth. This includes: (1) infrastructure for transport of water from various sources for human and industrial consumption, as well as effluent or recycling facilities, (2) capacity to generate energy such as hydro, thermal, solar, wind and nuclear, (3) means of transportation such as highways and railroads, sea ports and airports, (4) communication devices (accessibility and bandwidth of land and mobile phones, facsimile, radio, television, etc.), (5) housing, business parks and industrial estates, and (6) provision of social services (health, education, banking, etc. At both basic and advanced level).

A country with high levels of material wealth and high levels of spending can boos t its own economy as well as others ' by promoting consumerism. Interestingly, such nations also appear have a high borrowing capacity, which further fuels the economy in short to medium term. This may however, 'burn out' other types of wealth, detrimental in the long run.

The two sources of finance (internal and external) must be balanced with respect to the two sinks: purchase of products for immediate consumption and investment toward manufacturing activities leading to future wealth generation. Use of internal resources for immediate consumption is a fast and short- term catalyst for accelerating the economy, but it works differently in countries with consumerist and saving attitudes. Guiding the investment of internal resources for future wealth generation processes, such as manufacturing facilities along with the necessary infrastructure and support structure, must be the top priority of every Government. In contrast, external borrowing for immediate consumption on avoidable products that do not contribute to creation of any type of wealth should be resisted.

NATURAL WEALTH

The natural resources are those resources available to a nation by virtue of its geographical location, and can contribute to creation of wealth of one or more types. Natural resources, primarily, include materials and energy. Examples of natural material resources include soil (fertility), forests (wood, flowers, herbs, etc.) and minerals (ferrous and non- ferrous metals, ceramics, precious stones, natural polymers and composites). Natural energy sources include water and sunlight, besides coke, coal, crude oil, natural gas and nuclear fuel. Some resources may take both forms. For example, water is an input for farming and manufacturing activities, as well as a source of energy (from potential or kinetic, to electricity).

Waterways (rivers), long coastline for seaports and a terrain suitable for laying highways and railroads also add to the natural wealth, by bringing down the cost of transportation of people, raw materials and finished products.

INTELLECTUAL PROPERTY

Intellectual capital refers to the collection of innovative ideas that can potentially lead to creation of wealth. Ideas are primarily generated by people. Three factors affecting the intellectual capital of a nation are: (1) the number of innovative people, (2) their efficacy and efficiency for idea-generation, and (3) the mechanism for storing and exchanging innovative ideas.

At present, the mechanism for storing and exchanging innovative ideas is primarily provided by the legal framework for intellectual property rights (IPR), including patents, copyrights and trademarks. By obtaining a patent or copyright, the innovator or author is assured the right to commercialize and profit from his work (by own self or by granting the license to others) for a reasonable period. This also ensures that limited resources are not spent for 'reinventing the wheel'; a patented idea work may trigger other ideas; and the idea is not lost to humanity with the demise of the innovator. It can be seen (Table

1.4) that there is a sharp inequality between the patents filed and granted across the developed and developing countries. The future distribution of income will be greatly influenced by patenting and hence, there is an urgent need for developing countries to set up institutional mechanisms to deal with this recent phenomenon.

Related issues are the enforcement and social acceptance of the IPR framework, within a country as well as across countries. This has to be at all three levels: Government level (formulating appropriate IPR laws and ensuring their enforcement), manufacturer's level (honoring the IPR laws and regulations) and user level (purchase of products and services conforming to IPR laws).

Table 1.4: Patents filed and granted in selected countries in 1998

Country	Patent Applications			Patents granted		
	Residents	Non-residents	Total	Residents	Non-residents	Total
Japan	360338	77037	437375	125704	15744	141448
USA	141342	121445	262787	80292	67228	147520
Germany	67790	134981	202771	19271	32414	51685
Korea	50714	71036	121750	35900	16990	52890
China	14004	68285	82289	1653	3082	4735
India	2111	7997	10108	592	1119	1711

Source: World Intellectual Property Organization, http://www.wipo.int/ipstats/en

CULTURAL WEALTH

The cultural wealth refers to the traditions (processes) as well as the output (products) of cultural activities over several generations. Cultural traditions define the roles of people based on their characteristics such as age, gender and family of birth. They also define the relationships among family, friends and colleagues, as well as attitude towards others.

Cultural activities such as art, craft and architecture lead to products. Arts include fine arts (such as painting and sculpture) and performing arts (such as music, dance, plays and movies). Crafts are meant for producing exclusive or custom made products or decorations for products. Architecture deals with creation of enclosures and monuments for habitation, work, education, healthcare, social and religious purposes. The 'manufacture' of cultural products is becoming an important part of the economy.

ROLE IN WEALTH CREATION

There are three strong reasons for all nations to ensure a healthy manufacturing industry. First: the industry provides an array of products to end-users, fulfilling their basic needs necessary for survival and providing comforts and luxuries necessary for improving the standard of living. If a country does not produce certain products, it will have to import them from others that do.

Secondly, manufacturing is a force multiplier: it can create productive employment for the labour force. It also promotes growth of agricultural and services sectors: by creating demand for their products and services, and thereby creating even more jobs, leading to further generation of wealth.

Third, manufacturing is of strategic importance to any nation, especially those aspiring to be leaders. They can and should focus on all sectors of manufacturing. This helps in building up self- sufficiency, as well as overall development necessary for anticipating and catching future technological waves, which could emerge in unforeseen areas.

Countries with fewer resources can focus on a limited number of high value sectors, and trade them for other products and services with other countries.

Thus manufacturing activities fulfils physical needs of end-users, create employment, build up strategic competence and generate surplus wealth through exports for future development. Manufacturing has been the engine of growth for all major nations including USA, Japan and Germany. China and Korea clearly staked their development on the manufacturing sector, which was encouraged to grow at over 10% per year, compared to about 5% for India. I n 1980 the ratio of China’s GDP to India’s was less than 1, in 1990 it crossed 1, and by 2000 it exceeded 2. The growth of manufacturing also greatly contributed to improved standards of living; the penetration of consumer goods such as televisions, washing machines and air conditioners is today 5-20 times higher in China than that in India.

At present, according to the World Bank, the total value added in manufacturing activities worldwide is over US $ 5 trillion, accounting for 22% of the world economy.

Let us also examine the relation between manufacturing and other types of wealth.

As manufacturing activities become more and more efficient – owing to competition and scientific research – these consume less raw material (giving high yield) and energy per product. Designers are constantly shrinking the size of products through shape optimization and miniaturization techniques, which further reduce material consumption.

Reuse, refurbishment, replacement, replenishment and recycling techniques, along with development of eco- friendly materials and processes will gradually reduce the negative impact on nature.

Unfortunately, the rapid pace of commercial innovation (in which products are designed to become obsolete in a very short period, often within weeks) not only bewilders end-users – who have to learn how to use a new device all over again – but also offsets the above gains.

Fortunately, end-users are now demanding nature- friendly products, and forcing manufacturers to take the products back after their useful life. This will push manufacturers to accumulate minor innovations into longer - lasting products, use recyclable materials and adopt nature friendly manufacturing techniques.

The intellectual stimulation of conceptualizing and creating a new product to fulfill the needs of fellow human beings is supreme. This is fuelled by the competitive spirit to make more products, and make them better, faster and cheaper. These are often achieved by establishing and funding academic and research organizations, which trigger new ideas and create more entrepreneurs. The chain reaction rapidly builds up the intellectual wealth of a nation.

Only a few hundred years back (and even now in many developing countries), a family spent all the time 'manufacturing' its own food, clothing, shelter and tools. The large-scale manufacture of products has helped in fulfilling virtually every physical need of humans. This gives the people of developed nations potentially more leisure time for cultural activities. Secondly, the financial wealth gained by manufacturing activities and export gives a higher purchasing power. This implies that people of developed nations need to work fewer hours than those in developing nations for purchasing the same products.

However, the perceived need for more products (including luxury items) and social pressures drive most people to spend the hard saved leisure time also at work for earning more. This vicious cycle can be broken only by realizing that the total wealth comprises not only material, but also natural, intellectual and cultural wealth, as mentioned earlier.

In summary, manufacturing can be defined as the set of activities leading to and including the transformation of materials into physical products needed by end users or intermediaries using productivity enhancing tools, machines and methods. In contrast, service activities do not include physical transformation of materials, but are essential for supporting manufacturing activities. Manufacturing and wealth need to be seen and defined in their entirety. We see that there is a strong two-way relation between the two. A positive cycle will lead to gradual strengthening of both manufacturing activities and wealth of a nation. India is blessed with natural, intellectual and cultural wealth; these need to be properly harnessed to develop a responsible and sustainable manufacturing industry that becomes a role model for the rest of the world.

HISTORY AND GEOGRAPHY OF MANUFACTURING

In this section, we will briefly review the evolution of manufacturing industry in different parts of the world.

EVOLUTION OF MANUFACTURING

The industrial revolution in different parts of the world can be visualized as waves, as first proposed by Nikolai Kondratieff, a Russian economist in 1920s.

The first wave started in 18th century England with inventions related to the textile industry, steam engine and printing.

The second wave started in 19th century America and comprised of rapid developments related to automobile, railroad and telephones.

The third wave in 20th century was led by Japan, which focused on electronics and automation.

GROWTH OF MAJOR SECTORS

The location and growth of major manufacturing sectors is governed by several factors. The traditional factors include the proximity to raw materials, water, energy sources, labour force and customers. These are becoming less important because of their easier availability and mobility. Other factors that are becoming more important include proximity to ancillary industry, educational institutes, technology parks and transportation routes or hubs (including highways, railroads, sea ports and airports). The preference of investors and government incentives to develop a particular region, as well as real estate prices, climate and cultural life also influence the location.

Table 2.1: Major steel producing countries

	Value ($ bn)	Share in world (%) Exports		
Country/ Year	2001	1980	1990	2001
European Union (15)	57.9	52.9	57.0	44.7
Japan	13.5	20.4	11.8	10.5
Russian Fed.	6.0	-	-	4.6
United States	6.0	4.2	3.3	4.6
Korea, Rep. Of	5.8	2.2	3.4	4.5

Source: World Trade Organization, International Trade Statistics 2002

METAL AND AUTOMOBILE

Iron, steel and aluminium are the major metals required for industrial machinery, transport equipment (farming, automobiles, railroad and ships) and construction. Indeed, the production of metals continues to be a good indicator of economic activity.

The two major internal combustion engines were also first developed in Europe, by Germans: Nikolaus August Otto (1867) and Rudolph Diesel (1892). These effectively replaced steam engines. Earliest automobile manufacturers in Europe include: Volkswagen, Daimler -Benz (now Daimler -Chrysler) and Opel (a subsidiary of General Motors) from Germany; Renault and Citroen from France; Fiat from Italy and Volvo from Sweden.

Table 2.2: Major Automobile Manufacturing Countries

	Value ($bn.)	Share in world (%) export		
Country / Year	2001	1980	1990	2001
European Union (15)	270.9	52.8	53.8	48.0
Japan	80.2	19.8	20.8	14.2
United States	63.4	11.9	10.2	11.2
Canada	55.0	6.9	8.9	9.7
Mexico	30.7	0.3	1.5	5.4

Source: World Trade Organization, International Trade Statistics 2002

TEXTILE AND PAPER

Until about the turn of 18th century, textile was a domestic industry based entirely on human labour, especially for the spinning of yarn, one thread at a time using the spinning wheel. A series of mechanical innovations in Britain brought down the cost dramatically. Samuel Crompton’s the mule developed in 1779 produced quantities of fine, strong yarn. Other machines printed patterns on the surface of cotton or linen by means of rollers. In 1894, Northrup produced an automatic loom. Soon, cotton yard could be produced so cheaply in British factories that it displaced hand spun yard even in countries like India where the wages of workers were one sixth of those in Britain. The USA imposed protective tariffs against British imports to protect its domestic spinning industry. Gradually, the technology spread to other countries. Today China, United States, India and Pakistan together account for more than 50% of the production of textiles in the world. The British mills in Manchester and Lancashire closed down in 1970s.

Table 2.3: Major textile producing countries

	Value ($ bn.)	Share in world (%) exports		
Country/Year	*2001*	*1980*	*1990*	*2001*
European Union (15)	50.54	49.4	48.7	34.4
China	29.04	4.6	6.9	11.4
Korea, Rep. of	10.94	4.0	5.8	7.4
United States	10.49	6.8	4.8	7.1
Japan	6.19	9.3	5.6	4.2
India	5.90	2.1	2.1	3.8

Source: World Trade Organization, International Trade Statistics 2002

PETROLEUM AND CHEMICAL

Although the combustible properties of oil had been known since ancient times, its collection was limited to sites where the oil naturally and slowly percolated to the surface. In 1859, Edwin L. Drake drilled the first successful oil well 69 feet deep near Titusville in northwestern Pennsylvania in America. The discovery triggered the ‘oil rush’ as fortune seekers rushed to the site to buy land and construct oil derricks. Subsequently, new oil fields were discovered in Texas, California and Louisiana. By 1879, John Davison Rockefeller and the Standard Oil Company controlled 90% of the refining capacity in the United States. Until about 1910, the United States was producing 60-70% of world’s oil.

The Standard Oil Company monopoly was broken by the Anti- trust Action in 1911 to form Chevron, Mobil, Exxon and Amoco as separate corporate entities.

Table 2.4: Major chemical producing countries

	Value ($ bn.)	Share in world (%) exports		
Country/Year	2001	1980	1990	2001
European Union (15)	316.36	58.4	59.0	53.1
United States	82.30	14.8	13.3	13.8
Japan	30.62	4.7	5.3	5.1
Switzerland	25.60	4.0	4.6	4.3
Canada	14.99	2.5	2.2	2.5

Source: World Trade Organization, International Trade Statistics 2002

COMPUTER AND COMMUNICATION

Computer and communication technologies have affected every sector, directly or indirectly in the last two decades. The introduction of personal computers and growth of telecommunications in early 1980s triggered a revolution. By 1990, personal computers began entering homes. Soon, microprocessors were being embedded in many other tools and products also, such as cars and washing machines.

Table 2.5: Major computer firms worldwide (hardware and software)

Fortune Global Rank	Company name	Revenue ($ million)
19	Intl. Business Machines	85,866
70	Hewlett-Packard	45,226
131	Dell Computer	31,168
175	Microsoft	25,296
268	Sun Microsystems	18,250

Source: Fortune Global 500, http://www.fortune.com/lists/G500

INDIAN MANUFACTURING INDUSTRY

Indian science and technology, as well as manufacturing and trade, has an interesting history that has been poorly documented. Here we piece together a brief description about ancient, medieval and post-Independence India from various sources.

ANCIENT INDIA

India has a rich heritage of wisdom and knowledge embodied in *Vedas*, *Upavedas*, *Vedangas* and *Upanishads*. The word *Veda* implies the fountainhead of knowledge, required by mankind for spiritual as well as temporal (worldly) requirements. This was realized by (or revealed to) sages through observation, study and meditation of the physical world around them. Indeed, *Vigyana* implies insight or perception with freedom of thought. There are four *Vedas*: *Rigveda*, *Samaveda*, *Yajurveda* and *Atharvaveda*, claimed by scholars to be in existence 25,000 to 10,000 years B.C. The *Upavedas* are derived from *Vedas* and describe sciences, arts and engineering. These include: *Arthaveda* for economics and statecraft; *Ayurveda* for medicine and health; *Dhanurveda* for military science; *Gandharvaveda* for music and the arts; and *Sthapatyaveda* for architecture and engineering. The *Sthapatyaveda* contains the principles of realizing all kinds of manmade structures, and is derived from *Atharvaveda*. The *Vedangas*, meaning the limbs of *Veda*, enumerate the laws, codes and rituals for grammar, astronomy, righteous living, etc. A few works of sage scientists are listed in table 2.8.

Table 2.8: A few scientific works of ancient India

Sage	*Date*	*Work*	*Subject*
Kapil	3000 BC	Sankhya philosophy	Cosmology and psychology
Bharadwaj	800 BC	Vimana shastra, Yantra Sarvasva	Aviation and space sciences
Atreya	700 BC	Charak Samhita	Ayurvedic medicine
Kanad	600 BC		Atomic theory
Panini	600 BC	Astadhyayi	Grammar
Sushrut	450 BC	Sushrut Samhita	Anesthesia, plastic surgery
Dhanwantari	400 BC		Surgery
Kautilya	400 BC	Arthashastra	Economics
Parashara	100 BC		Botany
Nagarjuna	50 BC	Ras Ratnakar	Chemistry and metallurgy
Aryabhatt	500 AD	Shulva Sutra	Astronomy, mathematics
Varahamihr	550 AD	Panschasiddhant, Bruhad Samhita, Bruhad Jatak	Geography, constellation science, animal science
Brahmagupta	630 AD	Sputasiddhant	Astronomy, progressions
Sridharacharya	1000 AD		Quadratic equation
Bhaskaracharya	1150 AD	Lilavati, Bijaganita, Siddhantshiromani, Surya Siddhant	Algebra, arithmetic, geometry, mathematical techniques, gravity

Source: Compiled from various resources on the web

Greek literature indicates that Indian exports included a variety of spices, aromatics, quality textiles (muslins and cottons), ivory, high quality iron and gems, which were in high demand. In return, Rome supplied cut-gems, coral, wine, perfumes, papyrus, copper, tin and lead ingots to India. The trade balance was however, in India's favour, and the net payment was over fifty million *sesterces* per year in the form of gold or silver coinage, according to Pliny.

MEDIEVAL INDIA

There were several scholar - rulers who actively supported science and technology through grants from royal treasury. An example is Raja Bhoja (1018- 60) of Dhar-Malwa, well educated in sciences and arts, and a great engineer. He was the architect of Bhoj sagar, one of the largest artificial irrigation lakes of medieval India, started a university called *Bhoj Shala*, and provided a detailed network of roads connecting villages and towns in his magnum opus , *Somarangana Sutradhara*.

Table 2.9: Milestones in Indian iron and steel industry

Period	*Milestones*
300 BC	Porus presented Alexander 30 lbs of Indian iron. Kautilya (Chanakya) writes about minerals, including iron ores, and the art of extracting metals in ' Arthshastra' .
350 AD	A 8-metre wrought iron pillar erected near Delhi in memory of Chandragupta II. Another 16-metre iron pillar erected at Dhar (near Indore).
13th century	Massive iron beams used in the construction of the Sun temple, Konark
16th century	Indian steel known as ' Wootz' exported to Middle East and Europe
17th century	Manufacture of cannons, firearms and swords and agricultural implements. Suspension bridge built over Beas at Saugor with iron from Tendulkhma (MP). Iron smelter built at Porto Nova (Madras).
1870	Bengal Iron works established at Kulti.

Source: SAIL India, www.sail.co.in

POST INDEPENDENCE

At the time of independence in 1947, India was primarily an agrarian economy with little industrial development. There were very few industries confined to a few cities. Export strategy was not conducive to the country’s interest as it was seen as a mechanism to transfer raw material to the United Kingdom, so that they can sell finished products to their colonies. The social indicators were poor. The immediate task for the then government was to improve social and material condition and induce rapid growth in a stagnant economy.

Table 2.10: Composition of public sector outlays in various Five Year Plans

Five Year Plan	Agriculture & Irrigation	Power	Industry	Transport & Communication	Other
First Plan (1951-56)	30.6	13.3	6.1	26.5	23.5
Second Plan (1956-51)	20.7	9.6	23.5	28.3	18.0
Third Plan (1961-66)	20.4	14.6	23.0	24.7	17.4
Fourth Plan (1969-74)	24.0	15.4	22.8	20.4	17.4
Fifth Plan (1974-79)	22.2	18.8	24.3	17.4	17.3
Sixth Plan (1980-85)	23.9	28.1	15.5	16.2	16.3
Seventh Plan(1985-90)	20.4	28.2	13.4	17.4	20.7
Eighth Plan (1992-97)	20.6	26.6	10.8	23.7	18.3
Ninth Plan (1997-2002)	19.4	26.6	8.1	22.2	23.7

The growth of industrial output in India has consistently fallen short of targets laid down in the successive plans. The growth was reasonable during the first three Five Year Plans but for the next three Five Year Plans the industrialization lost direction. It was only in the sixth plan that some progress was achieved and the seventh plan, which marginally missed the targeted growth, showed distinct improvement.

Table 2.11: Growth rates of Indian industrial production (% per annum)

Plan	Period	Target	Actual
First	1951-2 to 1955-6	7.0	7.3
Second	1956-7 to 1960-1	10.5	6.6
Third	1961-2 to 1965-6	11.0	9.0
Fourth	1969-70 to 1973-4	12.0	4.7
Fifth	1974-5 to 1978-9	8.0	5.9
Sixth	1980-1 to 1984-5	8.0	5.9
Seventh	1985-6 to 1989-90	8.7	8.5

Source: Calculated from Various Sources

Though substantial investments were made in the Public sector, its share in the GDP remained around 25% in 1990. The infrastructure requirement for the growing industrialization could never be met. The share of infrastructure in the total public investment declined from almost 40% in the sixties to 34% in seventies. Besides infrastructure, the Public sector was expected to set up capacities in capital goods industries. Though these capacities were set up, they were poorly utilized. The contribution of public sector to gross saving (which is available for investments) was minimal and 1975 onwards it became negative.

Table 2.12. Profile of growth rates of Indian manufacturing sector

Time Period	Average Annual Growth Rates	Decadal Trend Growth Rates	Trend Growth Rate
1952-54	5.3	7.2	5.7
1955-59	7.4		
1960-64	9.3	5.7	
1965-69	3.9		
1970-74	2.8	4.4	
1975-79	5.3		
1980-84	4.8	7.6	
1985-89	8.9		
1990-94	5.1	7.1	
1995-99	7.9		
2000-01	5.3		
2001-02	2.9		

Trend growth rates have been computed using semi-logarithmic trend equation.

90'S DECADE

Faced with large trade deficits and overvalued currency, Government of India took major steps to liberalize the economy. The new industrial policy, unveiled on July 24th, 1991 aimed at eliminating barriers to entry and removing restrictions of Monopolies and Restrictive Trade Practices Act on the domestic industry to enable it to expand, for facing foreign competition, promoting direct foreign investment, restructuring the public sector and integrating the Indian economy with the global economy. Industrial licensing for all industries, except for few, was abolished. Foreign direct investment ranging from 51% to 100% was allowed depending on the industry.

The process of liberalization brings large decline in output in the early stages. In India also, a similar trend was observed. The manufacturing sector grew by only 0.2% in 1991-93 (immediately after liberalization) and climbed to 14% in 1995-96. It then however, lost s team and fell to 6% in 1997-1998.

At present, the Indian Manufacturing sector is exhibiting a Dual characteristic. While certain sectors like IT, pharmaceutical, automobile and fast moving consumer goods (FMCG) have shown unprecedented growth in the past five years, the core sectors of engineering goods, chemicals and small scale manufacturing, are in even poorer health under global pressure of open economy. The slump coupled with rising competitive pressure is forcing many Indian industries to restructure their operations. Indian industry is in fact witnessing unprecedented consolidations, takeovers, and mergers. Currently, the Indian manufacturing sector is grappling with the problem of competition from low priced mass consumption goods from Chinese and Asian markets and quality competition from products of advanced economies produced by superior technology. Import liberalization has hit a vast section of the manufacturing sector, though there are a few success stories as well. On export front, the manufacturing sector is not able to compete both due to the fact that our rivals in the global markets have had massive devaluation or depreciation of their local currencies.

COMPARATIVE EVALUATION

Let us evaluate the current status and direction of the Indian manufacturing industry with respect to the world. We will focus on two aspects: manufacturing strategy and competitiveness.

MANUFACTURING STRATEGY

In general, various countries have adopted two main strategies of growth of manufacturing sector. First is the import substituting industrialization and second is export led growth. Elements of former and latter can be combined in various proportions to suit the local needs and evolve domestic strategies. India and many countries in Latin America followed the former strategy, wherein, they tried to reduce their dependence on imports by developing and protecting industries related to import- substitution. The prime reasons for adopting this strategy is to reduce the dependence on foreign economies and to alleviate the foreign exchange constraint on import of capital goods. Protection in the form of high import tariffs on goods produced by these industries, making finance available at concessional rates, subsidies, tax holidays, etc. are accorded to import substituting industries. This strategy is suitable for establishing the manufacturing capability and nurturing it in the infant stages of the industry. However, the limited market size coupled with high investments required for manufacturing and R&D facilities restricts the number of manufacturers. Thus, there is little or no competition, both internal and external. This builds up monopolies and complacence, leading to poor quality, high price and low productivity. Eventually, the gap between domestic and ‘foreign’ products in terms of features, quality and price becomes too large to leap across, even with technology transfer, licensing or branch plants of multi-national companies. This is a characteristic of a closed economy and hardly practicable in an era of dismantling trade and non- trade barriers.

The second strategy, viz., export led growth is characterized by high level of exports in relation to national income. It is a challenging strategy. It requires high sensitivity to the market needs as well as technological developments worldwide, close inter face between the academia, industry and government, and high motivation to be world class. The results are impressive; this strategy yields the fastest growth in terms of employment, income generation and standard of living. Once the standard of living rises beyond a critical point, the motivation plateaus and the manufacturing industry starts giving way to the service sector.

COMPETITIVENESS

At present, the two major sources of information on India's competitive position vis -à-vis the other countries are available. These sources are: (i) World Competitiveness Yearbook (henceforth, WCY); and, (ii) Global Competitiveness Report (henceforth, GCR). The competitive ranking in WCY-2002 is based on four major factors: economic performance (74 criteria), government efficiency (84 criteria), business efficiency (66 criteria) and infrastructure availability (90 criteria).

Table 2.13: World Competitiveness Ranking

Country	*World Competitiveness Ranking (April)*				
	2002	*2001*	*2000*	*1999*	*1998*
USA	1	1	1	1	1
Singapore	5	2	2	2	2
Hong Kong	9	6	12	6	5
Germany	15	12	11	12	15
UK	16	19	16	19	13
Chile	20	24	25	25	27
France	22	25	22	23	22
Korea	27	28	28	41	36
Japan	30	26	24	24	20
China	31	33	30	29	21
Thailand	34	38	35	36	41
Brazil	35	31	31	34	35
Mexico	41	36	33	35	34
India	**42**	**41**	**39**	**42**	**38**
Argentina	49	43	41	33	30

Source: World Competitiveness Yearbook, 2002

Table 2.14: Current Competitiveness Index Ranks, 2001

Country	*Rank*
USA	2
Germany	4
UK	7
Singapore	10
France	12
Japan	15
HongKong	18
Korea	28
Chile	29
Brazil	30
India	**36**
Thailand	38
China	47
Mexico	51
Argentina	53

Source: Global Competitiveness Report, 2001-02

FUTURE DRIVERS AND ENABLERS

After a historical perspective of the manufacturing industry in different parts of the world as well as India, let us now turn our attention to the future scenario. We will first study a few major economic and technological drivers, and examine as to how they will influence the products and manufacturing processes. Finally, a few key methodologies, that will become essential to reach as well as maintain the competitive edge, are described.

ECONOMIC DRIVERS

Here we discuss two major economic drivers for future growth of manufacturing sector, especially in the Indian context: Globalization and Intellectual Property Rights.

GLOBALIZATION AND REGIONALISM

Globalization refers to integration of various local/domestic markets into larger/global markets. The process of globalization has enabled 'sourcing capital where it is cheapest, producing where it is most efficient, and selling where it is most profitable'. The markets could be for products or for factors of production, such as capital, labor or enterprise. The integration of markets takes place basically due to the removal of restrictions, both in terms of price barriers and non-price or quantity barriers. With the emergence of World Trade Organization(WTO), world over, the overall tariff rates (price barriers) are not going to increase. Also, the member countries have agreed to gradually eliminate non-price or quantity barriers. Thus, countries have to compete in global goods market mainly in terms of quality and price.

For example, India has a competitive cost-price advantage in mass consumption goods involving (cheap) labor. It also has an advantage in IT and niche engineering sectors, where it has established quality competitiveness. From this base, it could move up to product differentiation and technologically sophisticated product development to convert the challenges posed by globalization into opportunities.

INTELLECTUAL PROPERTY RIGHTS

As mentioned earlier, intellectual wealth – collection of innovative ideas – is an important part of the total wealth of a nation. The intellectual property rights (IPR) need to be protected and enforced by appropriate laws both inside and outside the country. This enables the creator of an original work to use and profit from his/her work for a certain period of time. In general, this ensures encouragement and reward for creative activities.

The IPRs are of mainly two forms. The first is copyrights for literary and artistic works (books, musical compositions, paintings, sculpture and films) for a minimum period of 50 years after the death of the author. Computer programs and databases also fall under this category. The second is rights for industrial property, including patents and trademarks. Patents are primarily for inventions pertaining to new designs, technologies and trade secrets. Enforcement of patents enables protecting the investments in research and development, and benefiting from the same through technology transfers or licensing mechanisms, usually for a period of 20 years. Trademarks refer to distinctive signs (such as brand names and company logos) that distinguish the goods or services of one firm from those of another. They enable fair competition between firms, and informed choices by customers. Trademarks may last indefinitely, as long as they continue to be distinctive.

We must recognize that the cost of a new drug reflects the huge expenditure on R&D required to arrive at its formulation. Similarly, the material and manufacturing cost of a music CD may be miniscule compared to the creative efforts and labor involved in its composition.

Recognition of IPR and its protection across national borders enables the development costs to be amortized over a larger population of buyers, thereby bringing down its price and making it more affordable to customers.

With the globalization of manufacturing, business and trade, the IPRs have become increasingly important and are a constant source of disputes between different countries. One main reason was that different countries had different extent of protection and modes of enforcement of IPRs. To introduce more order and predictability, as well as enable disputes to be settled more systematically, World Trade Organization (WTO) initiated the agreement on trade- related aspects of intellectual property rights (TRIPS). The agreement covers five major areas: (1) how basic principles of the trading system and other international intellectual property agreements should be applied, (2) how to give adequate protection to IPRs, (3) how countries should enforce those rights adequately in their own territories, (4) how to settle disputes on IPRs between members of the WTO, and (5) special transitional arrangements during the period when the new system is being introduced.

TECHNOLOGICAL DRIVERS

Here we study the major technological drivers that will influence the future products and processes: (1) Artificial intelligence and awareness, (2) Green materials and (3) Direct manufacturing.

ARTIFICIAL INTELLIGENCE AND AWARENESS

Artificial Intelligence (AI) is the capability of a non-human device (computer or computer -based system) to perform functions normally associated with human intelligence, such as reasoning and rational judgment. Research in AI started in 1950s at Stanford and MIT in USA, and continues more aggressively than ever before, in universities and research labs all over the world.

The earliest AI applications included expert systems for diagnostics purposes, ranging from medical and oil exploration to hardware repair and manufacturing defects analysis, where Japan quickly took a lead. Other areas of relatively recent success are natural language understanding, speech recognition, machine vision and robotics, besides chess. Some of these capabilities are combined in very recent applications such as intelligent pets.

The computing power in individual devices and their networking with each other will drive manufacturers to create a whole new array of products that will seem to have a life of their own. Today's food processors, washing machines and televisions will appear to be 'dumb' in comparison.

GREEN MATERIALS

Major materials for manufactured products include metals, polymers, ceramics and composites. Metals are divided into ferrous (iron, steel and their alloys) and non- ferrous (aluminium, chromium, copper, lead, magnesium, nickel, tin, titanium, zinc and others). Polymers include thermoplastics (polyethylene, polypropylene, polycarbonate, polyester, polyamides, etc.), thermosets (epoxies, melamines, phenolics, silicones, urethanes, etc.), elastomers (rubber), fibers and natural polymers (wood). Ceramics include carbides, oxides, nitrides and sulfides. Composites are combinations of two or more different types of materials (glass fiber reinforced plastics, ceramic metal matrix composites, etc.).

A typical automobile contains a variety of materials: steel body, aluminum engine block, plastic dashboard, rubber tires, ceramic spark plug and glass windows, to name a few. Ferrous metals contribute over 70% of the weight of a car, followed by non- ferrous metals (10%), the rest being plastics and ceramics. The demand for fuel-efficient vehicles, implying a reduction in weight, is driving the manufacturers towards lighter materials, mainly magnesium alloys, plastics, ceramics and composites. A major thrust in research includes manufacturing techniques suitable for the new materials. There are two major problems associated with the current approach to the use of materials in manufactured products. The first is the depletion of natural resources by mining and quarrying activities, including extraction of natural gas and oil (used for producing most of the polymers). The second is the dumping of products in landfills at the end of their life. Both activities – mining and dumping – create an imbalance in nature.

One way to address the above problem is to recycle the materials. Metals can be easily melted and mixed with right quantities of other elements to produce alloys of the desired composition and properties, and used in new products. The recycling of plastics and some ceramics poses a challenge that is being addressed. Parts made of composites or a multitude of materials (for example, computer chips) are not easy to recycle, since the separation of constituent materials can be difficult, if not impossible with current technology.

DIRECT MANUFACTURING

At present, a typical product is manufactured by assembling its components, which are in turn manufactured mainly by material shaping and/or material removal techniques. Material removal techniques such as turning, milling, drilling and grinding can be carried out on general-purpose machines, but involve wastage of material. Material shaping techniques such as casting, moulding and forming require part- specific tooling, which are expensive and take a long time to develop. In general, current manufacturing processes consume a high amount of various resources: material, energy and labor. They are economical only when the end- requirement is large.

The most recent and revolutionary development is nano or molecular manufacturing. The scanning tunneling microscope developed at IBM,USA in 1981 and its application for moving and positioning atoms in a pre-determined pattern has opened many new doors. This implies that a complex product, including its constituent parts of different materials, can be directly manufactured by moving appropriate molecules in appropriate positions, fast enough. While there is still a long wait for the day when a custom-made car, complete with body, chassis and engine will automatically emerge from a bath of material soup, physicists, material scientists and engineering researchers are excited about the prospect and working towards the goal.

METHODOLOGIES (ENABLERS)

To ride the waves of new technologies, we need appropriate vehicles. We present four enablers: (1) Bionics and Reverse engineering, (2) Continuous Innovation, (3) Knowledge Management and (4) Product Life-cycle engineering.

BIONICS AND REVERSE ENGINEERING

Bionics is the study of nature's materials, devices, processes and systems. The premise is that nature has already solved most of the problems we are grappling with. Biological systems are multifunctional, adaptive, nonlinear and complex; they have evolved over several millions years producing an equal number of ingenious methods and mechanisms.

Reverse engineering involves a detailed study of an existing product, usually made by a competitor, through disassembling its components if necessary, to determine its design (shape and dimensions), materials and manufacturing process, with the final aim of duplicating the product. An in-depth understanding of the relation between the product function, geometry, materials and process is essential to future improvements.

CONTINOUS INNOVATION

To achieve efficiency, reliability and recyclability approaching that of the nature, the current engineering products and processes need to be continuously improved through innovative ideas. This requires a passion for perfection, appropriate tools and techniques, and a creative environment.

KNOWLEDGE MANAGEMENT

Knowledge is a distilled and abstracted form of information; information itself being an abstraction of data. For example, the numbers in a table are data, the table or graph of the numbers is information, and the equation capturing the graph is knowledge. At present, the most important source of knowledge for manufacturing firms is from past experience, often gained by making costly mistakes.

PRODUCT LIFE-CYCLE AND ENGINEERING

Let us now turn our attention to how specialized knowledge will be used for developing products in the near future. We will also see why product design, in its complete sense, is the most important activity.

It is well known that the product design activity accounts for less than 10% of its cost. It is also understood that the purchase cost of a typical product may be less than 10% of its total cost to society (energy consumption, maintenance, repair, impact on health and ecology). A good design of any product can significantly reduce its total cost, and it is well worth spending more resources on product design activities.

Product life-cycle engineering implies considering all aspects of the life of a product, to evolve an optimal design that satisfies customer requirements with minimal total cost to society.

MANUFACTURING POLICY FRAMEWORK

We have seen why manufacturing activities are important for creating and sustaining wealth of all types. We have also studied the past history of manufacturing, analyzed the present situation and glimpsed future technologies and methodologies. Based on these, we propose a new vision and mission for the manufacturing industry, as well as policies to catalyze the industry in India. The policies are presented as the inter faces between the Government, academia and industry with respect to manufacturing. To the extent possible, we have attempted to evolve fresh ideas in each policy and in line with the proposed vision and mission.

MISSION AND VISION

VISION – BALANCED WEALTH CREATION

The vision should show the correct direction to align our manufacturing activities and help in assessing the current direction. The correct direction would be the one, which enables preserving and regenerating all types of wealth in a balanced manner. It must ensure prosperity for all levels of the society and for the current as well as future generations.

The proposed vision is: "To increase the prosperity for everyone in current as well as future generations, through creation and regeneration of all types of wealth – material, natural, intellectual and cultural – by encouraging and supporting appropriate manufacturing activities that respect nature and maintain a balance among various resources."

MISSION – LEADERS OF MANUFACTURING

There can be many ways of achieving the above vision: some faster than others, some which consume more resources than others, and some with more 'side effects' than others. It would be impossible to exactly predict the technological developments and their effect on the society 10, 20, 50 or 100 year s from now. Hence the proposed mission is: "T o identify, train, deploy and support the leaders for manufacturing, who will excel in product and process innovation, be committed to their profession and society, and passionately work towards the vision of balanced wealth creation."

Every generation produces a few memorable leaders such as Jamshetjee Tata, Dhirubhai Ambani and Narayan Murthy. There are many more in all sectors, at all levels, but less well known.

POLICIES FOR MANUFACTURING

The manufacturing technology policy must be aligned with the above vision and mission. It must allow people in different organizations related to the Government, academia and industry to identify themselves with the vision and integrate their own work with others to achieve the mission. The policy can be divided into four sets: academic policies, R&D policies, industry policies and economic policies. The first three sets of policies relate to the two-way inter face between three bodies: Government, academia and industry. The first set will deal with creating respect for manufacturing activities and a suitable environment for creating leaders. This can be best achieved by the interface between the Government and academia.

The second set deals with the creation of manufacturing leaders who will excel in product and process innovation. This is best achieved by the inter face between academia and industry.

The third set deals with the role of such leaders – who may be placed in Government organizations or in industry – to create world-class organizations for manufacturing-related activities.

The last set deals with an overall operating system for all organizations to function smoothly and work towards the vision with minimal hindrances. The Government, in consultation and cooperation with the academia and industry has an important role to play in achieving such an environment.

RESPECT FOR MANUFACTURING

FAVOURABLE ENVIRONMENT

Every child is born creative, but gradually develops mental blocks by the influence exerted by parents at home, teachers in school, friends in society and colleagues at work. Phrases such as ‘that is foolish’ and ‘it won’t work’ kill the creative enthusiasm of average people. Those who still defy the skeptics and keep working on their ideas are eventually brought down by a lack of resources to convert their ideas to reality.

All people, whether recognized as creative or not, will benefit by an environment which respects and nurtures creativity. A creative environment is one where the seeds of new ideas are produced by cross - fertilization from a rich variety of sources, grow into the trees of manufacturing facilities, and bear the fruit of products satisfying the needs of society. It is characterized by a freedom to think divergently, minimal noise and disturbance of all types, formal and informal mechanisms for networking for constructive criticism and cross - fertilization of ideas, and motivation, including social recognition.

KNOWLEDGE CREATION

Science and technology knowledge is perhaps the greatest asset of a nation, more important than physical assets such as machines and assembly plants. Multinational companies are happy to establish branch plants and fully owned subsidiaries in other countries, but fiercely protect their knowledge about the product design and its connection with the manufacturing process; technology transfers and licensing are no longer easily available. Every nation therefore, has to work hard to create, claim and commercialize its own niche areas of knowledge.

We have two sources for scientific and technical knowledge: discovery from ancient sources such as scriptures, and creation of new knowledge from science and technology. In addition, both streams must cooperate to cross - fertilize and cross check the knowledge for practical application, especially for manufacturing- related activities.

Modern science is based on inquiry, observation, experimentation, postulation and correlation to understand and explain the behavior of nature, and thus create new knowledge. Engineering involves the practical application of science to solve real-world problems, with the aim of utilizing materials and energy for human benefit. Technology is the application of engineering principles for a specific product or process. A nation must pursue all three: science, engineering and technology, for creating and applying new knowledge.

The Government research labs in India include the 40 labs of Council of Scientific and Industrial Research employing over 22,000 per sons, and the 50 labs of Defense Research and Development Organization, with over 30,000 per sons. Academic institutes include over 500 engineering colleges (with over 100,000 seats), 750 medical colleges and 1000 polytechnics, besides 8000 colleges for arts, science, commerce and teacher training. There are about 40 autonomous technical institutes, including 7 IIT s, 6 IIMs, IISc and 15

RECs (now NITs) supported by the Government. Today, India has the largest pool of qualified engineers, followed by USA, Germany and China.

ROLE OF THE MEDIA

The print and visual media has a very important role to play in creating a respect for manufacturing- related activities. Today, there is much discussion and consternation about the type of content published in newspapers, magazines, television, world-wide-web and movies, which greatly influence the minds and hearts of people, particularly the younger generation. The typical content includes news (political, business, social, sports and entertainment), advertisements, interviews, competitions, game shows, music, fiction and real- life based stories, most of which appear to contribute little towards promoting creativity, pursuit of knowledge and ethics, crucial for sustainable development. Even 'infotainment' appears to be primarily entertainment disguised as information.

OPERATING SYSTEM

Just as an operating system in a digital computer provides a backbone and a user -friendly environment for smooth functioning of various programs, the importance of a suitable operating system for the manufacturing industry can hardly be over -emphasized. The provision of local infrastructure, promotionary economic policies and transparency and accountability assume prime importance. These will enable tapping the full potential of Indian industry. In order to promote production and geographic distribution of infrastructure, it is essential to involve local population in developmental plans. Right now, the devolution of resources takes place from top to bottom and the local initiatives and participation in envisaging the developmental plans have not become the order of the day. We have already seen in the section of competitiveness that the inadequacy of infrastructure has led to pulling down of India's competitive position in the global economy. For example, investment in production of computer hardware depends on a stable uninterrupted power supply. Due to lack of it, investors have refrained from investing in this industry.

Economic catalysts like supportive exchange rate policies, simplification of procedures, implementation of reforms at the state levels, etc., are some of the remedies for promoting the manufacturing sector in India. Phenomenal amounts of cross -border transactions of money, due to lifting controls over capital mobility and technological advances have led to malpractices and speculation in financial markets. Scams have become the rule rather than an exception. Financial markets do not necessarily move according to the fundamentals of real economy or production. A more stringent legal regime is necessary to ensure that productive activities are at least rewarded as well as speculative activities, if not more. In enterprises where transparency is maintained and accountability is practiced, it inculcates confidence in the employees. Some of the success stories in Indian manufacturing sector have accepted precisely this strategy and we need to emulate it on a wider scale.

CONCLUSION

In a developing country like India, where over one fourth of population is still below the poverty line and inequalities in income distribution are increasing, the top priority would be to meet the commodity needs of the population while moving towards a global competitive edge. This is possible by promoting both agricultural and manufacturing sector s in a synergic manner, using innovative approaches that draw upon local resources: natural, intellectual and cultural. While the Western manufacturing industry is driven by aggressive power and intellectual property rights for local benefit, the Indian approach may embrace the principles of emotional bonding and prosperity for everyone – a more responsible and sustainable approach in the long run. The common factors in either approach are passion for manufacturing excellence and global outlook. These are characterized by system quality (zero complaints), cost competitiveness (zero waste) and delivery capability (zero delay) through appropriate technology and continuous innovation in products and processes. Achieving these is more of a mind game; success will crown only those who overcome complacency and a fatalist attitude. Such leaders of manufacturing need to be identified, trained, deployed and supported, and allowed to inspire others. The Government, academia and industry must work together to create a passion for manufacturing (*Kama*), facilitate its role in economy (*Ar tha*), leading to social development (*Dharma*) and eventually to global excellence in all spheres of life (*Moksha*).

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