The Future of Product Development in India*

AMARESH CHAKRABARTI

Centre for Product Design and Manufacturing, Indian Institute of Science, Bangalore 560012 INDIA

Abstract

Development of products – the artefacts of the act of designing - is an instrument of progress in a society. Product development both influences and is influenced by the growth of a society and its economy. India is one of the two fastest growing economies of the 21st century, with its industrial and services sectors fuelling its growth. In this paper, a brief historical and socio-economic account of India is used as a backdrop on which current drivers and roadblocks of its economic and social growth are painted, and it is within this context that an analysis of the current and future trends of product development practice, education and research is presented.A product is a reflection of the conditions, beliefs, aspirations and capability of a society. We take 'products' to mean artefacts of the act of designing, without limiting ourselves to only those created and exchanged for individual use in a mass market-economic context. Product in this definition therefore encompasses creation by both corporate sectors with profit as the primary motive, and others, such as non-government organizations (NGOs) for direct societal benefit of a community.

* To be Published in the Proceedings of The 17th CIRP Symposium on Future of Product Development, F-L Krause (Ed.), Berlin, Germany, 26-28 March 2007.

1 Introduction

The quantum and quality of product development as a practice impacts and is in turn impacted by that of education and research on product development. This paper will provide an analysis of the current progress in India in these three areas, and a view on the future of these in the next decades.

2 India: Some Facts and Figures

India is a country of 1.2 billion people, the second most populous after China. India accounts for approximately 3.4% of the world's landmass but is home to about 16% of the global population. The total literacy rate is estimated to be 65.38%. The economy of India is the third largest in the world as measured by purchasing power parity (PPP), with a gross domestic product (GDP) of US $3.611 trillion [Reuters, 2005]. When measured in USD exchange-rate terms, it is the tenth largest in the world, with a GDP of US $800.8 billion (2006) [The Hindu, 2005]. India is the second fastest growing major economy in the world, with a GDP growth rate of 8.9% at the end of the first quarter of 2006–2007. However, India's huge population results in a per capita income of $3,300 at PPP and $714 at nominal [The Hindu, 2005].

India's geography varies from mountain ranges to deserts, plains, hills and plateaus, while its climate varies from tropical in the south to the more temperate in the north. India's total cultivable area is 1.27 million km² (56.78% of total land area), which is decreasing due to pressure from an ever increasing population and urbanization.

India has a total water surface area of 0.3 million km² and receives an average annual rainfall of 1,100 mm. Irrigation accounts for 92% of the water utilization, and comprised 380 km² in 1974. This is expected to rise to 1,050 km² by 2025, with the balance accounted for by industrial and domestic consumers. India's inland water resources comprising rivers, canals, ponds and lakes, and marine resources comprising the east and west coasts of the Indian ocean and other gulfs and bays provide employment to nearly 6 million people in the fisheries sector. India is the sixth largest producer of fish in the world and second largest in inland fish production.

India's major mineral resources include Coal (fourth-largest reserves in the world), Iron ore, Manganese, Mica, Bauxite, Titanium ore, Chromite, Natural gas, Diamonds, Petroleum, Limestone and Thorium (world's largest). India's oil reserves meet 25% of the country's demand [Dutt and Sundaram, 2002].

India has a highly multilingual, pluralist, and tolerant society. It is the birthplace of two (Hinduism and Buddhism) of world's five major religions, with 325 languages spoken of the world's total of 2820 [Ministry of Education, Government of India Website].

3 Historial and Socio-Economic Background to Growth in Economy

Indian Civilisation has a (pre-) history of 12,000 years of development, starting from the early settlements in 10,000-8000 BC in the Ghaggar-Bhakhra Valley (in Afghanistan) [Chakrabarti, 1999].

It subsequently grew into urbanized settlements called Indus-Saravati Valley civilization that flourished during 3000-1500 BC, developing into cities like Mohen-jo-Daro, Harappa and others in north-western India and beyond, that practiced agriculture, domesticated animals, used uniform weights and measures, made tools and weapons, and traded with other cities in India and abroad. Evidence of well planned streets, a drainage system and water supply reveals their knowledge of urban planning, which included the world's first urban sanitation systems and the existence of a form of municipal government [Nehru, 1946].

This was followed by the growth of city States like Kashi and Vaishali, and subsequent large empires such as the Mauryas, the Guptas and the Mughals, integrating much of the current Afghanistan, Pakistan and India till 1700 AD. In the more recent past, India was under British colonization (1757-1947), before the post-independent era began in 1947.

Throughout its history, India has had a variety of trade links with other civilizations of the world, starting in its Indus Valley Phase with the Sumerian Civilisation in Iraq, through its later phases with various Arabian, European and Chinese civilizations. It is the trade links with the Arabs that enabled the learning of Indian numerals by the Arabs, which were later transmitted from Arabia to Europe that gave it its current misnomer of 'Arabic' numerals [Irfah, 1999; O'Connor and Robertson, 2000].

Before the British colonized India, it had one of the largest GDPs in the world. An estimate by Cambridge University historian Angus Maddison puts India's share of the world income as 22.6% in 1700, comparable to the whole of Europe's share of 23.3%, which fell to an abysmally low 3.8% in 1952 [The Hindu, 2005; Maddison, 2001].

India followed a socialist-inspired approach for most of its independent history, with strict government control over private sector participation, foreign trade, and foreign direct investment. However, since the early

1990s, India has gradually opened up its markets through economic reforms by reducing government controls on foreign trade and investment. Import tariff came down from the pre-liberalisation rate of 100% to the current maximum of 12.5%, with the revenue on duty collection down to 5% of the price of annual import. During the post-independence era, the GDP has seen a corresponding progress. During the socialist-inspired phase of the 1950s to 1970s, growth in the GDP was 3-3.5%, which increased to 5.4% in the 1980s. It gained momentum since the 1990s when the reforms began to take shape, which saw a growth rate of 6%. The GDP growth in the 2000s has been 6.0-8.5%.

Growth in the Indian economy is fuelled primarily by three sectors: agriculture, manufacturing and services.

3.1 Agriculture

Agriculture and allied sectors like forestry, logging and fishing accounted for 18.6% of the GDP in 2005 (declining from over 50% in 1947), and employed 60% of the total workforce [The Hindu, 2005]. It plays a significant role in the overall socio-economic development of India due to the largest number of people being employed within this sector. While yields per capita for all crops have steadily grown since the 1950s, and India is self sufficient in food production, there still is huge scope for improvement, as indiacted by its relatively low yields of 30-50% of the highest average in the world [Dutt and Sundaram, 2002]. Growth remains stagnant during the last decade in this sector. India ranks 2nd worldwide in farm output, after China.

3.2 Manufacturing

The manufacturing sector accounts for 27.6% of the GDP and employs 17% of the total workforce [The Hindu, 2005]. Economic reforms brought foreign competition, led to privatisation of certain public sector industries, opened up sectors hitherto reserved for the public sector and led to an expansion in the production of fast-moving consumer goods. Post-liberalisation, the Indian private sector was faced with foreign competition, including the threat of cheaper Chinese imports. It has since handled the change by squeezing costs, revamping management, focusing on designing new products and relying on low labour costs and technology [The Economist, 2003, 2004]. Indian industry is venturing further into the global market through its acquisitions, such as that of the Anglo-Dutch Corus Steel by Tata Steel or of Daewoo electronics Korea by Ashok-

Leyland. The credit-worthiness of the Tatas and Reliance Industries are currently better than that of GM and Ford. This sector is growing at 10-11% in the last few years. India ranks 14th worldwide in industrial output.

3.3 Services

India ranks 15th worldwide in services' output. This sector provides employment to 23% of the work force and has a growth rate of 7.5% in 1991–2000 up from 4.5% in 1951–80. It has the largest share in the GDP, accounting for 53.8% in 2005 up from 15% in 1950 [The Hindu, 2005]. Business services (information technology, information technology enabled services, business process outsourcing) are among the fastest growing sectors. India's IT industry accounted for only about 1% of the total GDP or 1/50th of the total services [Gordon and Gupta, 2003]. The growth in services is exemplified by the increase in the number of telephone lines from 5 million in 1990 to 140 million in 2006.

4 Major Drivers for Development

Gurcharan Das, former CEO of Proctor & Gamble India, sees these as the unique features of the current path of development in India: its primary reliance on its domestic market, focus on consumption rather than investment, on services more than on industry, and on high-tech rather than low-skilled manufacturing [Das, 2006]. While China's growth is fuelled primarily by improved infrastructure and foreign investment for selling low-priced, labour–intensive goods to the West, India's growth is mainly due to increase in domestic productivity and consumption. Consumption accounts for 64% of India's GDP, as opposed to 58% for Europe, 55% for Japan, and 42% for China. This model, he maintains, has resulted in better insulation of the economy from global fluctuations, and less increase in inequality among its people (measured by Gini index in a scale of 0 to 100, putting India at 33 (with China at 45, USA at 41 and Brazil at 59). Moreover 30-50% of the GDP growth is due to rising productivity rather than increase in the amount of capital or labour, making the economy less susceptible to the fluctuations in foreign investment.

We see six major drivers for the Indian economy: *market size, size of the working population, knowledge and ability, financial structure, availability of information, and open competition.*

The first driver is its *market size* with the growing middle class and its increasing purchasing power. It currently stands at 300 million, which is

similar to the size of the middle class in EU or USA. It has grown from the under 10% of the population in 1984-1985 to 25% in 2001 [Das, 2001].

The second driver to its economy is the *size of its working population*. India is the only major country in the world in which the percentage of people in the working age is estimated to increase in the next 25 years. The 2006 Census Projection report [Sikri, 2006] estimates the percentage of people in the age group of 15-59 (the working age) to increase from 57.7% of the total population in 2001 through 61% in 2006 to 64.3% in 2026.

The third major driver is the *knowledge, entrepreneurial capability and confidence* of the leadership in the working population. This stems from three strands. One is the tradition of knowledge cultivation over millennia among certain portions of the Indian population that led to major scientific, social and artistic advances in this subcontinent. However, knowledge in areas dominated by abstract thinking such as Philosophy and Mathematics grew in communities different from those that cultivated the knowledge of crafts and engineering. Entrepreneurial ability, similarly, has been cultivated by certain communities over centuries, as evidenced from these Indians flourishing in India and abroad as a business community. The confidence is a relatively new phenomenon. The archetypal Indian has been less than confident in the past in asserting her self, and demanding what she wants. This is probably a consequence of the recent success of India in the market place, in particular that of its IT industry which gave it global visibility, and the more recent success of its manufacturing sector that saw Indian companies beating the competition with its superior cost-sensitivity and understanding of the Indian market. An indicative figure is the growth in the number of IT-ITES professional employed in India, growing from 830,000 in 2003-04 to over one million in 2004-05.

The fourth major driver is the relatively sound *financial structure* of the Indian economy. The foreign exchange reserves reached US$ 143 billion in 2005, with the external debt to GDP ratio improving significantly from 38.7% in 1992 to 17.4% in 2005. The inflation rate has been a moderate 4.39-5.6% in the last five years. Foreign direct investment (FDI) has increased steadily, with none in 1991 to US$20 billion in 2005. Export also grew: while merchandise exports doubled in 3 years from US$52.7 billion (2002-2003) to US$102.7 billion (2005-2006), service exports doubled in the last two years. The national savings increased steadily to 28% in 2003-4 from 26% in the previous year [Gurumurthy, 2006].

The fifth major driver is the *awareness of the consumer and availability of information*. Authorities in India, both in government and industry, have traditionally been bureaucratic and non-transparent in providing information to its people. While the trend continues, there is growing strength in the consumer and human rights forums, in the recent introduction of the

Right to Information Act (RTI), and in the ever growing increase in the use of the internet as a medium that cannot be easily controlled or suppressed. This is seen in organisations like the Centre for Science and Environment that discovered the unusual proportion of pesticides in soft drinks sold by Coca Cola and Pepsi in India [CSE Press Release, 2006] leading to the effort to develop the national water standard, or the National Human Rights Commission that fought for the families of farmers who committed suicide as they could not repay debts after overuse of pesticides made pests resistant leading to low crop yields [NHRC website].

The sixth major driver is the *open access and competition*. Competition gives an opportunity to all competitors, and encourages development to be resource effective. Access of competitors brings with it cutting edge technologies and knowledge required for development.

5 Major Development Roadblocks

There are eight major roadblocks ahead of India in its development: poverty, poor health support, poor education, corruption, poor infrastructure, weak protection of knowledge, environmental degradation, and terrorism.

5.1 Poverty

The first roadblock is poverty. It remains a serious problem, even after declining significantly since independence due to the green revolution and economic reforms. While the percentage of people below poverty line was 36% during 1993-1994, it came down to 26% during 1999-2000, and is currently at 25% (2005). This is in comparison to 3% below poverty line in China [i-Watch website]. This means that, recent economic developments have primarily helped upper and middle class Indians. 260 Million Indians still live below poverty line, but a sustained growth of 8-9% could double per capita income in 10 years, with serious impact on reducing poverty.

5.2 Health and Sanitation

The second roadblock is the poor health and sanitation support. Apart from need for infrastructure and personnel, there is the imminent threat of AIDS as an epidemic. In India, an estimated 5.2 million people are living with HIV/AIDS (14% of world total), while over 270,000 people died of AIDS in 2005. In comparison, the number of people living with HIV/AIDS in the

USA in same year was 1 million. In developing countries, 6.8 million people need life saving drugs for AIDS immediately, while only 1.65 million people are actually receiving it [Avert website]. India's health expenditure is US$99 per capita compared to China's US$261, Brazil's US$561 and Russia's US$565 in PPP terms [UNDP report, 2005].

5.3 Education and Research

The third roadblock is the lack of uniform and quality education to the population, and inadequate research towards knowledge creation. Literacy rates rose from 18.3% in 1951 to 64.8 % in 2001, the current literacy ratio of India is 65.38% with male literacy at 75.85% and female literacy at 54.16%. This means that one in every three people in India cannot read and write. In contrast, 99% of Chinese children attend school for 9 years, ensuring a high level of literacy. In rural India, 75% of schools have one teacher for several classes in a single classroom. The public expenditure on higher education is a further indicator: while China spends $2798 per student enrolled in higher education and has a higher enrolment rate of 13%, India spends $406 per student with an enrolment rate of 11%. It is estimated that only 25% of engineers, 15% of commerce graduates and 10% of general graduates are seen by MNCs as employable from India [Srivastava, 2006]. Poor salary of teachers and poor infrastructure are seen as major reasons for this state, as exemplified by the typical paltry starting salary of Rs2,50,000 (US$5500 per year) for an academic with a PhD, which is roughly the same as that of a senior call centre employee with high school education only. Starting salary for a graduate engineer in India is typically Rs4,00,000 (US$88,000). In China the salary could be as high as US$60,000 for a full professor, as opposed to Rs6,00,000 (US$13,300) for a similar one in India [Aiyer, 2006]. The difficulty in attracting high quality professionals in higher education is indicated by the difficulty IITs are facing, in some cases with a shortfall of 30% of teachers [Jayaraman, 2006]. While the total number of research papers published from India has increased from 72,874 (1993-1007) to 77,201 (197-2001), this is a miniscule percentage of the world output (about 2%) when contrasted with that of the USA (37-35%), UK (9-9.5%), Germany (8-9%) or Japan (8.5-9%). China has a world share of 2-3% [King, 2004].

5.4 Corruption, Apathy and Inefficiency

A major reason for the low turnaround in school level education (and many of the above roadblocks) is the existence of huge corruption at all levels. It

takes the form of bribes, evasion of tax and exchange controls, embezzlement, etc. The economic reforms of 1991 reduced the red tape, bureaucracy and the Licence Raj that had strangled private enterprise and was blamed for the corruption and inefficiencies [Delong, 2004]. Yet, a 2005 study by Transparency International (TI) India found that more than half of those surveyed had firsthand experience of paying bribe or peddling influence to get a job done in a public office [Centre for Media Studies, 2005]. According to some estimates, India's corruption may be declining, as its index on corruption moved from 2.8 in 2003 (0 being the most corrupt) to 2.9 in 2005 [Immigration and Refugee Board of Canada website, 2005]. The chief economic consequences of corruption are the loss to the exchequer, an unhealthy climate for investment and an increase in the cost of government-subsidised services. The TI India study estimates the monetary value of petty corruption in 11 basic services provided by the government, like education, healthcare, judiciary, police, etc., to be around Rs.2,106.8 billion [Centre for Media Studies, 2005].

5.5 Infrastructure

The fifth roadblock is inadequacy of physical infrastructure and basic amenities. Since independence, India has allocated nearly half of the total outlay of its five-year plans for infrastructural development. Development of infrastructure was completely in the hands of the public sector and was plagued by corruption, bureaucratic inefficiencies, urban-bias and an inability to scale investment. India's low spending on power, water, construction, transportation, telecommunications and real estate, at $31 billion or 6% of GDP, compared to China's $260 billion or 20% of its GDP in 2002 has often been quoted as a major roadblock in its development.

5.6 Protection of Knowledge

The sixth roadblock to development is the lack of adequate protection of knowledge capital. The recognition of knowledge as property is relatively recent in India, which has led to plagiarism, both by foreign companies trying to steal traditional knowledge as seen in attempts to patent Basmati Rice, Neem and Haldi by US and Japanese companies [Shiva, 1999], as well as copying of designs and products by Indian companies. Without effective measures for stopping piracy of intellectual property including traditional knowledge, development will be costlier than otherwise.

5.7 Environmental Degradation

In some estimates, the environmental degradation in India has a faster rate growth than that of GDP. For instance, the ratio of CO2 to GDP growth in India has been on the rise [Azar et al. 2002]. There is also a steady increase in fossil carbon emissions in India (as in China and Brazil), which is also indicative of increased pollution in the country. Since growth is typically proportional to energy consumption, this is to be expected, given the low quality of coal reserves in India. The other environmental threats come from rapid development in a country that has no comprehensive environmental protection policy. For instance, India is one of the fastest growing mobile phone markets in the world, with 14.17 million users till May 2003. The market is rising by over 100 per cent every year, thus making it one of the most lucrative places for global players and cell phone providers. This, combined with rapid obsolesce due to malfunction or development of new features will create significant volumes of waste, with the additional threat from e-waste headed towards developing countries like India, Pakistan and China [Kaur, 2004]. Environmental degradation is likely to increase rapidly, unless explicit measures are taken to rein in pollution, including development and deployment of cleaner technologies, products and services.

5.8 Militancy and Terrorism

Wikipedia defines terrorism as "peacetime equivalent of war crime", [Wikipedia Website]. Terrorism and insurgency is on the rise in India, in three kinds of conflicts:

- One is the Kashmiri separatist movement that is primarily funded and fuelled by Pakistan and its intelligence wing ISI [Human Rights Watch Website]. According to some estimates at least 84,000 civilians lost their lives in Jammu and Kashmir due to militancy. It reached its peak in 1994 when 6043 incidents took place, and declined since, although an average of 2500 incidents still take place each year [Raman, 2001]. Some fight in the name of Islam, some to take away Kashmir to Pakistan, and others to make Kashmir independent. There are an estimated 3000 militants operating in the Jammu-Kashmir valley alone.
- The other is the separatist movements in some of the Northwestern states of India such as Assam and Nagaland, also believed to be aided and abated by ISI using Bangladesh and Myanmar as training bases.
- The third is the ‘people’s war’ group’ or PWG, an extreme form of communist movement prevalent in the regions under extreme poverty such as in Andhra Pradesh, Jharkhand and Bihar. The movement is primarily a

reaction to the sharp difference in economy and social status of the poor, and the social apathy and corruption in reducing this gap.

Terrorism could be form major roadblock against growth as this leads to damage of human and capital resources, and disrupts peace which is a major prerequisite to growth in any economy.

6 A Brief History of Product and Technology Development in India

Technology and product development in India is divided here into three broad phases: pre-history till independence phase, pre-liberalisation phase, and post-liberalisation phase.

6.1 Prehistory till Independence

Since prehistory through the colonialization by the Brisitsh, India had been developing various indigenous technologies in various phases, some examples are given below. In civil engineering, the Indus-Sarasvati Civilization was the world's first to build planned towns with underground drainage, civil sanitation, hydraulic engineering, and air-cooling architecture. While the other ancient civilizations of the world were small towns with one central complex, this civilization had the distinction of being spread across many towns, covering a region about half the size of Europe. Weights and linguistic symbols were standardized across this vast geography, for a period of over 1,000 years. Oven-baked bricks were invented in India in approximately 4,000 BC. Water management was highly advanced from Harappan times onwards. For example, in Gujarat, Chandragupta built the Sudarshan Lake in late 4th century BC. The Vijayanagar Empire built such a large lake in 14th – 15th century AD that it has more construction material than the Great Wall of China. What some historians call the “Persian Wheel” is actually pre-Mughal and indigenous to India.

Since ancient times, Greeks and Romans extensively imported textiles from India. One of the earliest industries relocated from India to Britain was textiles and became the first major success of the Industrial Revolution, with Britain replacing India as the world's leading textile exporter. What is less known is the fact that the technology, designs and even raw cotton were initially imported from India while, in parallel, India's indigenous textile mills were outlawed by the British. Textiles and steel were the mainstays of the British Industrial Revolution, both of which had their origins in India. Recent discoveries reveal that iron was known in the Ganga

valley in mid second millennium BC. In the mid-first millennium BC, the Indian wootz steel was very popular in Persian courts for making swords. Rust-free steel was an Indian invention, and remained an Indian skill for centuries. Delhi's famous iron pillar, dated 402 AD, is considered a metallurgical marvel and shows minimal signs of rust. The famous 'Damascus steel' swords were made from Indian steel imported by Europeans. The acclaimed Sheffield steel in the UK was Indian crucible steel. European scientists worked for decades to learn to reverse-engineer crucible steel making, and in this process, made modern alloy design that led to the development of physical metallurgy in Europe.

Shipbuilding was one of India's major export industries until the British dismantled it and formally banned it. Medieval Arab sailors purchased their boats in India. The Portuguese also continued to get their boats from India and not Europe. Some of the world's largest and most sophisticated ships were built in India and China [Malhotra and Patel, 2003].

6.2 Pre-liberalisation

During the socialist-inspired period (1950-1980), industrial development was followed in a mixed economy, where areas were clearly demarcated between public and private sectors. The public sectors had guaranteed sale, and little incentive was there for making products efficient or for delivering on time or within projected cost. Some public sector areas with missions encouraged by the government (such as the Nuclear and Aerospace sectors) developed indigenous solutions of high quality (from satellites to turbines), but with sub-optimal use of resources. In most private sectors, little competition was on offer, and corruption could be used to maintain monopoly or oligopoly, as evidenced by nearly the same product being sold by the same companies for decades. In general, the industrial and services sector grew very slowly during this period. While the protectionist regime gave the industrial sector time to produce almost all items indigenously, it did not give the incentive for these to be improved or expanded resource-effectively. A side effect of this period was creation of a pool of engineers of high level of competence, knowledge and leadership quality.

6.3 Post-liberalisation

During the post-liberalization period (1990-2005), product development was influenced by four factors: Removal of the License Raj, entry of the external competitors, privatization of Public Sectors, and Telecom-IT revolution. While the first three helped open up the market for both internal and

external competitors and forced Indian companies to become more competitive, the last one provided the first tangible means, visibility and confidence for Indian companies to compete in the global market. The result has been encouraging, with the sector growing at an unprecedented 10-12%.

This culminated in the development of India's first indigenously developed passenger car 'Indica' by Tata Motors in 1999, SUV 'Scorpio' by Mahindra & Mahindra in 2002 (which made sales in the whole segment grow from the earlier 14 per cent to over 42% in the three years after its introduction), and development of the first indigenous combat aircraft 'LCA' by the Aeronautical Development Agency (ADA) in 2001. However, manufacturing still accounts for a much lower portion of the GDP than Services (unlike in China where it is over 40% of the GDP) and there is ample scope for job creation through mass manufacturing.

India saw an increasing trend among global enterprises such as Daimler-Chrysler, GM or Nokia for setting up their R&D base in India for supporting innovation. Of the Fortune 500 companies, 125 now has R&D bases in India [Das, 2006]. Often these R&D units are led by the highly competent and knowledgeable engineers created and nurtured by the public sector organisations. The overall output of this sector has been products and services for the burgeoning middle class with better quality and variety, both from Indian and international companies. There is a related increase in the number of patent filings, and its rate of growth in the last decade has been the second fastest (365%) in the world after China (557%).

A related movement has taken place in organizing grassroots level innovation, in which local problems are solved by locals with the help of trained designers. Organizations aiding this movement include Engineers Without Borders [www.ewb-usa.org], Think-cycle [www.thinkcycle.org] and the National Innovation Foundation [www.nifindia.org].

7 Current Issues with Product Development in India

Current growth in Indian economy is fuelled by two sectors: manufacturing and services. Since product development forms the engine of growth in these sectors, and one sector fuels growth in the other (e.g., increase in telephone services impact the development of communication products, and increase in automobile sales fuel growth of its allied services), effective practice of product development should have crucial impact on growth. Micro-economic factors that accounted for more than 50% of the GDP growth in over 50% of the OECD countries in the 1990s are: fostering firm creation and entrepreneurship; fostering innovation and technol-

ogy diffusion; seizing the benefits of ICT; and enhancing human capital as well as realising its potential. As seen in these, two of the four drivers directly indicate the importance of product development as crucial for growth [OECD, 2005]. The following lessons can be learnt from the story of development in general, and that of products and services in India:

- Availability of market is crucial for growth of product development, and effective product development should drive sustained growth of the market. India has a growing captive market of middle class which constitutes a third of its population, and which is far from saturated. To add to this, this population is far more sensitive to benefit-cost ratio and far less brand-loyal than its counterparts in the West, as evidenced from its average sampling of 6.2 brands a year in a category compared to 2 brands per year in the West. To penetrate the lower portion of this middle class, Tata Motors recently announced development of its US$2000 passenger car [Tata, 2005]. The increasing trend of product design and development outsourcing for customers outside India presents a further market opportunity. Indian companies have started developing and selling products in countries abroad, based not only on the cost differential but also on competing performance. Opportunities exist for considerable expansion of manufacturing from its current high-tech, high-skilled manufacturing to low-skilled mass manufacturing as in China, lending scope for a more widespread industrial revolution. On the whole the market is opportune for product development.
- India also has a huge potential market that comprises the remaining two thirds of its people, waiting for products that can meet their needs at their income levels. Any product in this category will have significant impact on the Indian society esp. its larger and more neglected sections.
- The next requirement for effective product development is the availability of people at the working age. This number is high and will be increasing further in the next 25 years. Since much of the world population including China will see a significant reduction in its workforce in the next decades while seeing a greater need for products, Indian workforce should play a primary role in global product development.
- The third is the continuous need for knowledge (for abstract reasoning as well as for concrete implementation), entrepreneurial ability and motivation to compete in the local and global product development scenario. Traditionally Indian society tried to develop these abilities in separate communities, whereas product development needs a happy integration of them. While the current situation seems adequate, this is bound to change for the worse unless steps are taken to ensure steady flow of leading professionals with updated knowledge, ability and motivation. One reason is the comprehensive lack of mass education in product development and entrepreneurship. In contrast to China's 644,000 and USA's

222,000 engineers produced in 2004, India has 215,000, of which 112,000 were graduate engineers (as opposed to China's 351,000 and USA's 137,000) [Azar, 2005]. The number of design students graduating is substantially less, about 500 in India (2 designers per 1000 engineers) as opposed to 10,000 in China (15 for 1000). Two positive points in this regard are the increased product development activity in India at the R&D bases of Indian and foreign companies, and due to a greater availability of knowledge in this area via the internet and the WWW.

- A specific issue with availability of knowledge essential for product development in India is the following. A product must fulfil, resource-effectively, stakeholder need of three kinds: technical, ergonomic and aesthetic. While traditional design departments and institutions in India have been synthesis-centred, and focused mainly on aesthetic and ergonomic needs, economic fulfilment of technical needs remained largely outside the realms of design education. On the other hand, institutions for technology education have been analysis-centred primarily teaching existing technologies, without emphasis or education on synthetic thinking, design processes, methodologies and tools. This bi-polarity must give way to a more holistic design education with focus on all aspects of the product, a philosophy on which the design programme at Indian Institute of Science has been founded.
- Most roadblocks to development seem to present new opportunities for product development. Infrastructure must improve for providing sustained growth, and a greater expenditure in this sector should create new market and product development opportunity. Health and safety sector is rapidly developing as a service sector, but there is also opportunity for product development (including development of inexpensive drugs, especially for the 'bottom of the pyramid' that remains un-served. Education and environment should present new technology, product and service opportunities, impacting on reducing poverty, corruption and insurgency.
- Protection of knowledge is essential for a suitable environment for product development, especially the threat that traditional knowledge faces from being stolen. This is generally more harmful than mere copying of specific products, as it deprives a much greater number of people of their livelihood for whom choice is far limited.

8 Future of Product Development Practice

The trends in future product development in India are the following:

- Specialized R&D sectors will thrive in supporting high-end knowledge-intensive areas, as projected by the estimated growth of semiconductor industry from US$3.25 billion in 2006 to US$43 billion in 2015.
- While a highly consumerist but also highly cost-sensitive and brand-non-loyal middle class will continue to be the major focus for product development, this will extend further to the lower part of the middle class and to the rest of the pyramid where major opportunities will emerge.
- The major growth sectors are aerospace, automobile, infrastructure, consumer electronics and health. Environment and safety will be major concerns in and drivers of product development as consumers become more aware, unite as a community, and demand more, and as stricter laws are implemented for reining in environmental degradation and safety.
- The design outsourcing work for, as well as export of products to other countries should continue to grow, as long as good product development personnel can be created and nurtured, or knowledge needed made available through partnerships. Work has already shifted from modelling, via analysis to bread-and-butter designs (where cost is the prime consideration), and is likely to climb the value chain further for more performance-led design jobs (where intellectual property is created). This should be a major driver for quality education in product development, and should see subsequent growth of collaborative partnerships between industries and academia, where market understanding will marry specialist knowledge.
- Designer jobs are projected to increase in the USA at over 9% per year in the next decade. In Australia, the number of design jobs grew at a similar rate, from 23913 to 47750 in the decade 1996-2006. Similar trend is likely to be seen in India, possibly at a faster rate due to the larger actualised demand in the developing economy.
- A trend in public sectors will be increased conversion of (spin-off) technologies into products, providing opportunities for employing designers and generating revenues.
- Human capital is one of the major resources of India. With all the difficulties that it brings with it, the largely chaotic, tolerant, multicultural, multi-lingual, democratic, pluralist ambience of India will remain a favourable, distinguishing factor in shaping its innovation potential, continuing to play its role in creating innovative designers and product developers. As Gurumoorthy [2005] points out, handling of chaotic situations in an unstructured manner is an unavoidable aspect of living in India, and should help enhance its innovation potential!

9 Future of Education and research in Product Development

Education in product development must improve at all levels across regions and social strata, with the following trends:

- There will be manifold increase in design education in India. The trend is already seen in the growth of its design education programmes from 2 in the 1960s, to 3 in the 1990s, to about 15 in 2006, creating about 500 designers. However, only half of these are graduate degree programmes or above, limited to five Indian Institutes of Technology (IIT), Indian Institute of Science (IISc), and the School of Planning and Architecture, Delhi) with a total output of about 100 [Das, 2006]. Design education is likely to spread to all IITs, National Institutes of Technology and many private engineering colleges or specialist institutions, leading to at least an order of magnitude increase in the number of designers in the next decade.
- Education will be limited mainly to undergraduate and postgraduate degrees and diplomas, and will be offered in many areas of specialisation such as automobile design, engineering design, and aeronautical design, visual communication, animation design and crafts design.
- Gurumoorthy [2006] notes that Indian designers have been typically weak in turning ideas into reality. Quality education imparting questioning ability, problem definition skills, strategy level skills and implementation skills for innovation will be the key differentiator for competitiveness, distinguishing leading professionals from rote product developers. Training in holistic design thinking, creativity, collaboration, environment and entrepreneurship, integrating all aspects of stakeholder need, will be necessary. This combined skill should help designers become self-sufficient, as is the case in developed countries where most designers are self-employed (e.g. 33% US designers were self-employed in 2004).
- Programmes will increase in training product developers as well as grassroots innovators with up-to-date knowledge of design thinking, methodology and tools. Education will see many collaborative partnerships, between academia, government and industry in India and abroad.
- Related bodies for recognition and control of design practice, education and research will be brought into being as the design community becomes bigger and more united. This should see introduction of design policy (a draft is already being considered), council and academies, and growth in design conferences, journals and research funding programmes.
- A major obstacle in promoting education in this area is the lack of mass awareness about design. While humans are natural problem solvers and good at synthetic thinking that is basic to designing, this is largely

suppressed during formal education and only analytical thinking is promoted. Programmes of mass awareness, and education on design and product development should become as commonplace as Physics and Chemistry, promoting design thinking - a fundamental intellectual activity across disciplines. Education must be provided at all levels from primary education onwards, so as to nurture design thinking since childhood.

- A major obstacle in promoting research in this area is the pathetic lack of awareness of the intellectual content of research in this area, especially among traditional scientists and engineers who control much of the academic resources in India. The other major difficulty arises from the degree of fragmentation among design academia about the communality, substance and intellectual challenges in their community. However, demand for competent personnel to fuel growth in this sector will drive growth in demand for trained design teachers, especially those with training in academic research in this area, whose numbers are miniscule at present. This will be a major driver for growth in PhD research programmes in this area, which is currently offered in only three institutions across India, with IISc pioneering with the first PhD programme in the country. To put things into perspective, there are very few design teachers (10-20) in India that hold a PhD degree in an area of design research, with most others holding a postgraduate degree or diploma.
- The quality of teachers and higher education in general, and that in design in particular will critically depend on three factors: an internationally competitive pay scale to attract the best to join academia in India, an open competition in regard to recruitment of teachers in higher education institutions based on merit, and a higher investment (from both foreign and Indigenous bodies) in the academic infrastructure.
- Major research-areas in the Indian context will include creativity, collaboration, knowledge and environment. India-specific research areas in human factors, culture and aesthetics will also grow. Major advances will be seen in interfaces with emerging technology areas, such as in nano- and bio-technology. Applications will be seen at both ends: the traditional craft-based, low volume, small scale industry sectors as well as the high end aerospace, automobile and allied sectors.

10 Conclusions

Future is always hard to predict. This paper is an attempt to predict trends in product development in India in the context of its historical and socio-economic past and present. Major trends in practice are likely to be on ex-

tending focus on the current middle class to the needs of the bottom of the pyramid and to low-cost mass scale manufacturing for job creation, while that in education and research will be on design thinking, creativity, collaboration, knowledge and environment. Collaboration across the globe will play a major role in shaping these, as will global laws for protection of knowledge and environment. Availability of education and basic infrastructure, across regions and economic strata, would play a major role in this transformation.

References

Aiyar, Pallavi (2006) China Hunts Abroad for Academic Talent. Asia Times Online, Feb 18 http://www.atimes.com/atimes/China_Business/HB18Cb05.html

Avert Website, http://www.avert.org/indiaaids.htm

Azar, Christian, Holmberg, John, Karlsson, Sten (2002) Decoupling - Past Trends and Prospects for the Future. Environmental Advisory Council, Ministry of Environment, Stockholm, ISSN 0375-250X, http://www.sou.gov.se/mvb/pdf/decoupling.pdf

Centre for Media Studies (2005) India Corruption Study 2005 to Improve Governance Volume I _key Highlights. Transparency International India, New Delhi, http://www.cmsindia.org/cms/events/corruption.pdf

Chakrabarti, Dilip Kumar. Chakrabarti D.K. 1999a. Bharatvarsher Pragitihas (The Prehistory of India in Bengali), Itihas Granthamala 6. Ananda Publishers, Calcutta.

Das, Gurcharan (2001) India's Growing Middle Class. The Globalist, 5 Nov, http://www.theglobalist.com/DBWeb/StoryId.aspx?StoryId=2195

Das, Gurcharan (2006) The Indian Model - An economy unshackled. 85(4), Foreign Affairs, http://www.ccsindia.org/ccsindia/gdas/images/The-Indian-Model-Foreign-Affairs.pdf

Das, LK (2006) Towards Degrees in Design, Indo-US Workshop on Design Engineering, Chakrabarti and Subrahmanian (Eds), Bangalore

Datt, Ruddar & Sundharam, K.P.M.. "28", Indian Economy, 485-491.

Datt, Ruddar & Sundharam, KPM (2002) Indian Economy, S. Chand & Co., New Delhi, 839-841

DeLong, JB (2004) India Since Independence: An Analytic Growth Narrative. Dani Rodrik (ed), Modern Economic Growth: Analytical Country Studies, http://ksghome.harvard.edu/~drodrik/Growth%20volume/DeLong-India.pdf

Department of Education, Education Statistics. Government of India, http://education.nic.in/htmlweb/edusta.htm
Economic structure, The Economist, October 6, 2003.
Gereffi, Gary, Wadhwa, Vivek, Rising, Ben, Kalakuntla, Kiran, Cheong, Soomi, Weng, Qi, Lingamneni, Nishanth (2005) Framing the engineering Outsourcing Debate – Placing The United States on a Level Playing Field with China and India. Master of Engineering Program, Duke University, http://memp.pratt.duke.edu/downloads/duke_outsourcing_2005.pdf
Gordon, Jim and Gupta, Poonam (2003) Understanding India's Services Revolution. November 12, 2003.
Gurumoorthy, B (2005) Evolution of Our Product Development Tradition. Presentation Slides, In Round Table on New Product Development, IIM Bangalore Management Review, 17(3), 81-96
Gurumoorthy, B (2006) New Product Development. Presentation Slides, In Closing Workshop on Collaboration Between East and West, 6th International Conference on Tools and Methods for Competitive Engineering (TMCE2006), Ljubliana
Gurumurthy, S (2006) Defaming as a profession, to doing down businesses and communities. New India Press, Nov 5, http://www.newindpress.com/Column.asp?ID=IEH20020222231458&P=old
Human Rights Watch Website, http://www.hrw.org/campaigns/kashmir/1994/kashmir94-01.htm
i watch, India-China Comparison, http://www.wakeupcall.org/china_india_comparision/china_india_comparision.php
Ifrah, Georges (1999) The Universal History of Numbers: From Prehistory to the Invention of the Computer. Wiley, ISBN 0-471-37568-3
Immigration and Refugee Board of Canada (2005) India. 14 Dec, http://www.irb-cisr.gc.ca/en/research/ndp/ref/?action=view&doc=ind100769ex
Indian manufacturers learn to compete, The Economist, 12 February 2004.
Jayaraman, Killugudi (2006) Indian Research Institutes Face Tough Time. 21 Aug, Chemical World, RSC Advancing the Chemical Sciences, http://www.rsc.org/chemistryworld/News/2006/August/21080601.asp
Kaur, Arvinder, Toxic cellphones may be dumped in India. Rediff.com, May 14, http://inhome.rediff.com/money/2004/may/14mobile.htm
King, David (2004) The Scientific Impact of Nations - What Different Countries Get for Their Research Funding. Nature, 430, 15 July
Maddison, Angus (2001) The World Economy: A Millennial Perspective. OECD, Paris
Nehru, J (1946). Discovery of India. Penguin Books. ISBN 0-14-303103-1

NHRC Website, http://nhrc.nic.in/
O'Connor, JJ, Robertson EF (2000) Indian Numerals. MacTutor History of Mathematics Archive, School of Mathematics and Statistics, University of St. Andrews, Scotland
OECD (2005) Micro-Policies for Growth and Productivity Final Report. http://www.oecd.org/dataoecd/40/58/34941809.pdf
Press Release (2006) Soft Drinks Still Unsafe, Centre for Science and Environment, New Delhi, Aug 2 http://www.cseindia.org/misc/cola-indepth/cola2006/cola_press2006.htm
Rajiv Malhotra and Jay Patel (2003) History of Indian Science & Technology: Overview of the 20-Volume Series. http://www.indianscience.org/
Raman, B (2001) The Surrogate War in Kashmir. Business Line Internet edition, The Hindu, March 8, http://www.hinduonnet.com/businessline/2001/03/08/stories/040855ks.htm
Reuters (2005) India grows 8.1 pct in Apr-June, outlook strong. Sept 30
Shiva, Vandana (1999) The US Patent System Legalizes Theft and Biopiracy. The Hindu, July 28, http://www.organicconsumers.org/Patent/uspatsys.cfm
Sikri, DK (2006) Population Projections for India and States 2001-2026. Report on the Technical Group on Population Projections Constituted by the National Commission on Population, Office of the registrar General and Census Commissioner, India
Srivastava, Siddharth (2006) India's Million Dollar Education Question. Sept 22, Asia Times Online, http://www.atimes.com/atimes/South_Asia/HI22Df02.html
Tata, Ratan (2005) Rs 1 lakh car by 2008. The Financial Express, India May 7, http://www.tata.com/tata_motors/media/20050507.htm
The Hindu (2005) Of Oxford, economics, empire, and freedom. Oct 2
UNDP Report (2005) Human Development Trends 2005, http://hdr.undp.org/docs/statistics/data/flash/2005/2005.html
Wikipedia website, http://en.wikipedia.org/wiki/Terrorism_in_India