Indian National Academy Of Engineering

VISION, MISSION, AND VALUES
INAE 2037

EDITORS
Prem Krishna
K V Raghavan
S S Chakraborty
Purnendu Ghosh

INDIAN NATIONAL ACADEMY OF ENGINEERING

The Indian National Academy of Engineering (INAE) is an autonomous institution partly supported by the Department of Science and Technology, Govt. of India and is recognized as a Scientific and Industrial Research Organization (SIRO) by the Department of Scientific and Industrial Research, Govt. of India.

REGISTERED OFFICE

Gurgaon

Indian National Academy of Engineering
6th Floor, Unit No. 604-609, SPAZE I-Tech Park, Tower A, Sector 49, Sohna Road
Gurgaon – 122 002 (India)
Phone: (91) – 0124 – 4239480
Fax: (91) – 0124 – 4239481
Email : inaehq@inae.in
Website : www.inae.in

New Delhi

Indian National Academy of Engineering
6th Floor, Vishwakarma Bhawan, IIT Campus, Shaheed Jeet Singh Marg
New Delhi – 110 016 (India)
Phone: (91) – 011 – 26582635
Fax: (91) – 011 -26856635
Email : inaehq@inae.in
Website : www.inae.in

Published by the Indian National Academy of Engineering, New Delhi
Printed at the Popular Printers, M.D. Road, Jaipur, Phone : 0141-2609294, 2606591

INDIAN NATIONAL ACADEMY OF ENGINEERING

INAE 2037
VISION, MISSION, AND VALUES

EDITORS

Prem Krishna
K V Raghavan
S S Chakraborty
Purnendu Ghosh

Vision does not occur in the eye.
It occurs in the mind.

INAE 2037
VISION, MISSION, AND VALUES

VISION DOCUMENT COMMITTEE

Prem Krishna

K V Raghavan

Arun K De

S C Dutta Roy

C V R Murty

Alok Nath Dey

AUTHORS

Prem Krishna

K V Raghavan

Purnendu Ghosh

S K Bhattacharyya

Rajeev Shorey

Nagesh Iyer

Sanak Mishra

A B Bhattacharyya

P K Sikdar

S Gangopadhyaya

V K Agarwal

EDITORS

Prem Krishna

K V Raghavan

S S Chakraborty

Purnendu Ghosh

C O N T E N T S

FOREWORD

Indian National Academy of Engineering has completed twenty five years of its existence during which time it has made significant contributions to build a strong and developing India. The asset of the Academy is 700 plus fellows, 70 plus young associates, and 60 plus foreign fellows. The individuals are eminent, with marked track record of contributions that have made India and the world find engineering solutions to many challenges. Many individuals in the Academy have built institutes of excellence, executed large programmes and built a credible foundation of competence for us to leap forward and build India of our aspirations through our actions and dedication.

The nature and tenor of aspirations can vary at Government, organisation and individual levels. I have an aspiration too, which I wish to share with you: “India, to emerge in next ten years, as a country where all the citizens have quality life and stature matching with their competence and character. The citizens work in a cohesive and ethical way, with shared goals and objectives to achieve sustainability with equity. The country is secure internally and externally. The country respects other countries and their citizens. Also the citizens of India are inspired by commitment and compassion to improve the earth planet”.

We all know the differences between aspiration and reality. We face real and unique challenges in areas of water, healthcare, education, energy, food, infrastructure, security, etc. These challenges are intertwined with one another in a complex manner. In addition, sustainability of progress and equity has placed unparalleled demands requiring imaginative as well as realistic solutions from scientists, engineers and policy makers.

Science is made visible and practical by engineers. Technologists and policy makers, along with the citizens define the path of progress for the nation. It is the multidisciplinary vector, vision and competence of the teams which make a nation grow in stature and flourish in credibility to bring in the desired changes for realising the aspirations.

INAE - 2037 document, prepared under the leadership of Prof. Prem Krishna and his colleagues of the team and with the involvement of a large number of Fellows have envisioned future India in some key and vital areas of challenges and opportunities. Prof. Prem Krishna and his colleagues have done a commendable job through introspections, and analyses focussing on fresh perspectives. Though future is generally known to be unpredictable, we must be aware of the challenges and the possibilities, and perceive the future in best possible manner while being prepared for breakthroughs, transformative innovations and discoveries made possible by extraordinary persons of merit, which would change not only the path but even the trajectory and the destination of India by 2037.

INAE - 2037 also maps a road that lies ahead for the Academy to pro-act, initiate and work for building the requisite expertise and evolve the mechanisms to contribute to the growth and prosperity of the Nation.

It has been perceived that education, science, technology, innovation, policies, and collaborations within and outside India, etc. have to work in a cohesive manner in a team mode to convert challenges to opportunities. The Academy is in a unique position to work with industries to suitably address the challenges facing India today and to take up the leadership role in fostering and developing select emerging technologies of relevance to us. It is in this context that INAE - 2037 (2037 AD is the year when the Academy shall be 50 years in existence) becomes a reference source material to discuss and work out the details and improve on the vision contents. It is also important for the country to decide the agenda, set the pace and scale up the performance and get away from disadvantageous directions and unproductive paths. For this to happen in time in India, we need to identify directions and evolve methods. It is my firm belief that in this context the Academy is the most competent body of immense value and relevance to the country.

I am looking forward to the fellows; young and not so young, and to my friends in our sister academies worldwide (under the auspices of Committee of Academies of Engineering and Technology Sciences) and our collaborators through the medium of bilateral collaborations with foreign academies to participate in a conscious and judicious manner with well-defined strategies to build a better and sustainable India and the Planet Earth. As an example we may cite our collaboration with CAETS on clean energy technologies and with foreign academies on advanced manufacturing, clean coal, solar energy and health care etc. that are significant engagements of merit and growing importance to us.

I wish to have your suggestions and whole hearted participation to meet the growing challenges to fulfill the aspirations of India. It is indeed true that India of the future will face numerous challenges, and is full of opportunities and excitement. India would be what we aspire for and try to achieve. The country has provided us with opportunities which are as enjoyable as nuts, but we have to crack these nuts to enjoy the fruits. We, in the Academy, have the experience and the intellectual resources to offer and demonstrate robust solutions, and suggest viable course for building a strong and prosperous India which is secure, and inclusive, respecting the dignity of human life and appreciating the grandeur of nature.

I wish my fellow colleagues in the Academy a magnificent year 2014.

Baldev Raj
President, INAE

April 2014

PREFACE

The Indian National Academy of Engineering (INAE) completed 25 years of its establishment in 2012, which was celebrated with a range of activities spread over a year. When releasing a coffee table book entitled “Glimpses of Indian Engineering Achievements”, dealt with the recent history, was released it was decided to envision the future engineering scenario of the country and to draw up a road map of future activities of the INAE. This VISION document is the outcome of this decision. The vision period would see the Academy completing its 50 illustrious years.

A committee consisting of the undersigned, Prof. Arun K De, Prof. S C Dutta Roy, Dr. K V Raghavan, Prof. C V R Murty and Dr. Alok Nath Dey was set up for the purpose of preparing VISION – 2037 document. Based upon the initial ground work made by the committee, views drawn from the various sections of the Academy and from a study of similar publications, a draft document was prepared by Dr. K V Raghavan and the undersigned. This was presented to the fellows in a meeting held at Delhi on April 18, 2013, which also marked the culmination of the yearlong Silver Jubilee celebrations of the Academy. Valuable suggestions were received, and the draft document found wide acceptance.

A vital component of VISION - 2037 document is the scenarios presented on various important sectors of engineering activity by subject experts. These sectoral scenarios provide important future projections. The effort for writing on the following topics by the following colleagues is gratefully acknowledged: Prof. Purnendu Ghosh – Food and Agriculture, Prof. S K Bhattacharyya – Habitat, Dr. K V Raghavan – Energy, Dr. Rajeev Shorey – Healthcare, Dr Nagesh Iyer – Education, Dr. Sanak Mishra – Manufacturing, Prof. A B Bhattacharyya – Electronics and Communication, Prof. P K Sikdar and Dr. S Gangopadhyaya, Road, Mr. V K Agarwal - Railways. A note on Manufacturing by Prof. Manoj Tewari also served as a good resource.

The document has been finalised by an Editorial Committee consisting of the undersigned, Dr. K V Raghavan, Prof. S S Chakraborty and Prof. Purnendu Ghosh.

The ideas and suggestions received from time to time from the Fellows are gratefully acknowledged. I also wish to place on record the support received from Brig. S C Marwaha and Brig. Rajan Minocha and their team at the INAE office, particularly Mrs Pratigya Laur, who helped in coordinating this activity.

Prem Krishna

April, 2014 **Chair, Vision Document Committee**

VISION, MISSION AND VALUES

VISION, MISSION AND VALUES

The 20th century witnessed lasting imprints of science and engineering in all spheres of human activity. The additional challenges for the 21st century are in sustaining, indeed in enhancing these imprints, under growing ecological, societal and economic constraints; all targeted towards holistic development. India, the largest and the second most populous democracy, is fully committed to employing science and technology for effectively meeting its future human and infrastructure development needs.

The Indian National Academy of Engineering (INAE) has been closely monitoring the emerging advances in various engineering fields in India and abroad against the backdrop of internationalization of engineering knowledge and its utilization. The Academy has discerned glimpses of the major challenges before the Indian engineering community in vital areas viz. enhancing quality of life, facilitating sustainability, improved domestic and overseas connectivity, both physical and virtual, and ensuring safe and secure environment against external and internal threats. The magnitude and complexities of the associated tasks are enormous due to their great engineering challenges as well as entrenched economic and social barriers. Promoting engineering excellence through creative human endeavours in all these spheres is one of the perceived mandates of the Academy. Fully convinced of the outstanding capabilities of its fellowship and its inherent strengths in developing shared values, teamwork, creative knowledge and strong academic linkages, INAE now endeavours to chart its own growth path for the next 25 years. As the apex Body of Indian engineering, the Academy tunes its own Vision to that path of development. The core issues are highlighted in Figure-1 and it brings out the interconnected societal and engineering challenges.

THE VISION

In spite of a mileu of uncertainties and roadblocks, INAE foresees significant potentials to emerge from the Indian growth picture in 2037 and beyond. From an engineering perspective, sustainable living in India means enhancing the ability of its people to meet their basic necessities of food, housing, water and sanitation with reduced disparities and increased equality of outcomes. Foremost among the Indian challenges are those related to providing quality education, innovation centred research, aspiration-driven manufacturing, worldclass expertise in electronics and communication and value engineered public services. The growth of socioeconomically vital sectors has to be driven through efficient mobility and connectivity through multimodal road and high speed railway networks, well connected airways, low carbon energy automobiles and access to space and deep-sea environments for socio-economic benefits. The INAE foresees the need for more robust and technology backed disaster warning systems supported by failproof mitigation measures for ensuring secured lives for its people.

An effort is made by the INAE to prepare a broad roadmap for its endeavours till 2037 with the proper identification of the future role of Indian engineering in facilitating solutions for the most pressing problems of the nation. With its shared values, teamwork of its creative fellowship and strong national and international linkages, the INAE has crafted its long term vision in the envisioned areas to become:

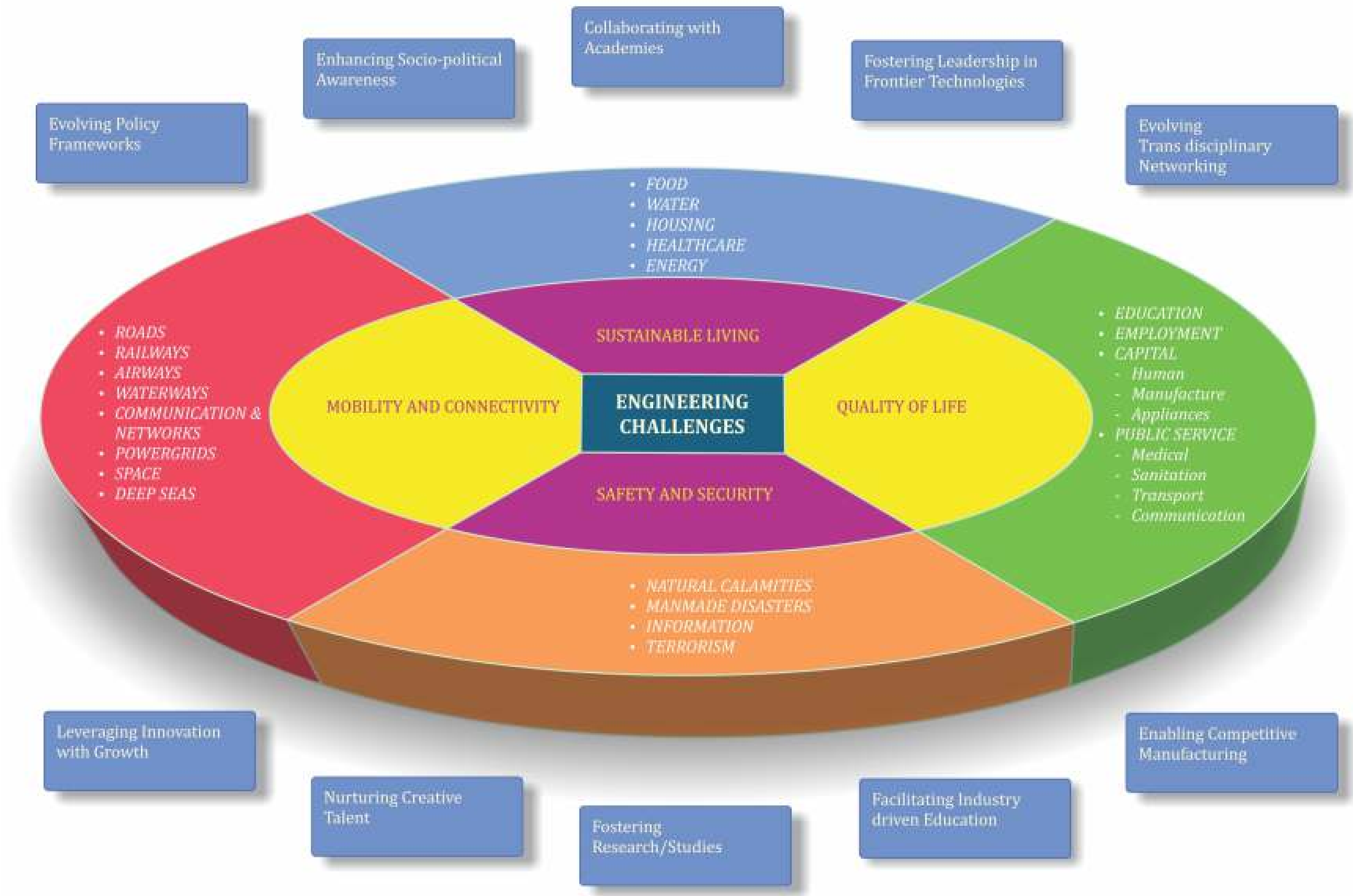


Fig. 1 : Major Indian Challenges and INAE Initiatives

- An internationally accredited Engineering Academy in achieving, upholding and enriching Engineering excellence at individual, group and institution levels employing high ethical norms in its practices
- A nationally-acclaimed academic body with profound interdisciplinary engineering capabilities to bridge the gap between
  - o Engineering and scientific disciplines
  - o Academy, R&D and industry
- A Forerunner in networking and broad-banding the Indian institutional knowledge in frontline engineering areas through the processes of reengineering and revitalization
- A highly competent and professionally managed academic body probing the impact of contemporary engineering advances on the society, industry, government and other stakeholders
- An institution with exceptional capabilities in framing, developing and advising on implementation of engineering, science and technology policies by the government and international bodies and
- An acknowledged leader with unique abilities to formulate national level engineering research development roadmaps, new pathways and portfolios in areas of high relevance in envisioned areas.

THE MISSION

It is imperative that anchors and guide posts have to be established by the Academy in order to bring higher clarity of achieving its vision through operationalization of the envisioned tasks during the next 25 years. Perhaps an issue of deep-seated importance is the need to work on the socio-political canvas to create an adequate degree of sensitization to highlight the importance of engineering for all round growth of the nation encompassing all facets of development in envisioned areas. Without this, it may be well-nigh impossible to make the needed headway. The INAE is committed to adopt a mission mode approach to serve the engineering community and the society at large through its well directed programmes in envisioned areas by:

Evolving policy framework for Government of India specifying set of principles and long term goals that form the basis for its planning and development processes.

Enhancing socio-political awareness of engineering profession through interaction with experts, stakeholders and administrators on issues that affect large sections of the Indian society.

Collaborating with other academies in interdisciplinary areas where major transformational change has to be brought in through joint action

Fostering leadership in frontier technologies to build a sense of confidence in the ability of the academy to respond to major developments in new engineering frontiers with internal intellectual strength.

Evolving trans-disciplinary networking to execute programmes in areas of high national importance which require inter-institutional collaboration to solve complex engineering problems

Leveraging innovation with growth through execution of specific programmes which can place Indian engineering science ahead of global competitors

Nurturing creative talent in frontier engineering areas in formative years of education or research for attractive career advancement

Fostering research/studies to create new knowledge leading to industrial innovation in new product and process development areas

Facilitating industry driven education in frontline application areas like nanotechnology, microelectronics, product engineering etc., for human resource development for R&D and manufacture

Enabling competitive manufacturing to support growth in newly developing markets in emerging products of high consumer importance and

Participating in International Council of Academies of Engineering and Technological Sciences (CAETS) and other international bodies in a sustained manner in areas of synergic interests.

THE VALUES

With hard work, untiring efforts, perseverance even under adversity and committed fellowship, the INAE will strive to achieve academic, intellectual, social and moral excellence in all its activities. Fuelling this conviction are INAE's core values of inquiry, engineering proficiency and accountability. The INAE passionately believes that they will ensure rewarding and inspiring engineering outcomes contributing to nation building.

ROADMAP FOR REALISING THE VISION

ROADMAP FOR REALISING THE VISION

The future of India, which emerged from the shackles of a prolonged foreign rule only about six decades back, is full of exciting opportunities and daunting challenges. However, envisioning the state of the country twenty five years hence is fraught with uncertainties, given the pace of technological changes and developments. Whereas it is obvious that the population, already large, is set to go on increasing with the estimated number of nearly 1.4 billion in 2022 and 1.6 billion in 2037, it is known that whatever the requirements of our society for a better living are, they are in very short supply. This is evident in the large difference between India's world rank in terms of Gross Domestic Product (GDP) and Human Development Index (HDI) - 10th in the former and 134th in the latter. Moreover, in terms of innovativeness, the nation projects itself poorly, the Global Innovation Index (GII) ranking it at 65th. The complexity of our society presents itself in a unique and very wide spectrum of languages, religious beliefs, vocations and economic levels (and the huge disparities therein). The state of the political and governance system of the country continues to be in transition after centuries of imposed rule over the country. The vagaries of the world economic order impose additional complexities and so also the changing climatic and environmental systems, casting a shadow over the sustainability of life itself as we know it on earth.

However, from this milieu of uncertainties, some significant prospects emerge from the Indian growth picture (up to 2037) which need to be given due consideration. India has become the third largest economy in the world perhaps only behind USA and China. India will also enjoy a unique demographic dividend as compared to several developed countries in the world in terms of an impressive ratio of working age (15-64 years) / non-working age (0-14 & 65 and above) population. The other obvious trend is India's fast growing urban population to become 600 million strong in 2037, i.e., almost twice the current population of the US. Alongside these developments is the burgeoning Indian middle class with its purchasing power nearly doubling between 2010 and 2025. Of course, India needs to turn all of these to its real advantage by ushering a high growth policy regime which is holistic, inclusive and sustainable. The effort by INAE to envision "Scenario 2037"is made against this background and to draw a roadmap for its future activities contributing to the growth of relevant engineering science and technology.

1. BASIC TENETS FOR SUSTAINABLE LIVING

On an engineering and technological perspective, sustainable living may mean to enhance the ability of the Indian population to meet its basic necessities with reduced disparities and enhanced equality of outcomes. Novel resources have to be developed which prevent or reverse the current level of environmental degradation. The eight Millennium Development Goals (MDGs) of United Nations Organization (UNO) have to form part of the blue print of Indian growth which needs to be mainly driven by human resources and basic infrastructure. Evolving Innovation driven engineering approaches for promoting sustainable development in the context of India reducing the levels of crunching poverty to be achieved not merely by resource transfer but through providing and empowering habitat provisions with disaster preparedness and mitigation occupying a prominent position. The nation, with its long shorelines, large wetlands particularly in the Gangetic delta areas, is vulnerable to effects of climate change, and extreme weather events in particular. Concern for such negatives and action against the same must form a significant component of sustainable development. Further, it will not be long before there will be a clamour for India to reduce the energy intensiveness of its economy and to reduce its carbon emissions. Focus must be on what may be called carbon-light construction and manufacturing. Along with innovations, our systems will also have to change. Business As Usual (BAU) scenarios will not get us on to the highly desired, indeed essential steep growth curve. The systems to be changed cover the gamut - starting from education, to human resource development, to research and development, to intensifying technical and engineering input into policy discussions, to acknowledging a development perspective in resource allocation to facilitate national growth.

1.1 Food and Agriculture

The demand for food will be increasing due to population increase and shift away from cereals and pulses towards fruits and vegetables, dairy products i.e. high value and protein rich foods. A second green revolution underpinned by technology and driven by markets and partnerships will be the most effective response to meet these demands.

The Academy is best positioned to facilitate interactions between stake holders, policy makers, industry, agri- R & D units. While arable land is a scarce resource, reclaiming fallow or saline lands for agriculture is possible, by engineering intensive interventions. However, in this effort, the Academy will focus on smooth connections between production and the social institutions of production - agriculture and agrarian, to ensure holistic development while satisfying the increasing demands of society. Efficient market access to agricultural products, going beyond transportation and reaching into storage of perishables is also a concern of Indian engineering community. Agricultural engineering to boost productivity in agriculture sector must occupy our minds. The Academy will work in coordination with other agencies of the government towards enhancing crop productivity, irrigation access, efficient use of water and fertilizer to foreclose the possibilities of food scarcity. In a similar vein, it will also interact with agri-processing industries to ensure technologically most effective value addition to agri-products that also enhances the profitability in agriculture. The Academy's involvement will then cover the gamut of agricultural activities, however, based on the need to improve crop productivity through engineering and technology. The Academy perceives a long-term inclusive sustainable development.

Saving on losses during agricultural operations is interlinked with renewable energy and smart grids to realize optimum results which should benefit farmers and nation's common citizen. Nutrition at affordable cost needs to be met in a scientific manner keeping in mind food habits and culture in different parts of the country. Organic food, genetic crops, waste land and climate change resistant agriculture, novel processing, value addition etc. offer a number of frontiers which need to be crossed in a comprehensive manner.

1.2 Poverty Alleviation

Poverty manifests itself as a cause of sustaining itself. Contributions towards poverty alleviation efforts must include engineering solutions for ennobling habitats, creating every kind of opportunity and facility needed for economic growth and all round development - be it mobility, water supply, sanitation, solid waste disposal, power, communication and irrigation. INAE intends to focus on the development of indigenous capabilities in maximizing the utility of engineering interventions in alleviating the poverty and in enabling an individual's creativity and enterprise to contribute to national development. Innovations, in the nature of both blue-sky thinking and Jugaad will play the anchoring role in such economic transformations of society. Offering employment of the kind that is inviting, challenging, probing and visibly productive is a sure and effective way of lifting the poor out of poverty. Engineering education, enriched by dynamism and innovations, offers this opportunity. Even artisan training, skill development programmes and diploma education in engineering are stepping stones to climb up the ladder of increased opportunities and social status. Engineering education also offers a roadmap for reducing inequality in society, as may be reckoned by Gini coefficient.

1.3 Habitat

The fabric of life itself is critically affected by the availability or otherwise of safe and comfortable living spaces for the Indian population. The housing shortage at the end of 11th Five Year Plan was around 26.5 million units and much of what is available is deficient in quality. There is an urgent need to address this issue both for rural as well as urban areas. Added to this is the challenge of finding enough urban space to cater to the rapid urbanisation of India's population, which may rise to 40% in the middle 30s. By 2037, there may be close to 100 cities with a population of over 1.0 million. This will also require good quality high-rise construction to accommodate the increasing numbers of households. An estimated 10 million houses need to be added each year. The magnitude of the problem is further compounded on account of unplanned growth of human settlements and ineffective land management in most of the urban centres which calls for their removal / resettlements. The requirements of housing that are emerging, as mentioned above, will also throw up the issues of dire shortage of skilled technical manpower and engineers, particularly in civil engineering and allied fields. There are likewise the issues of natural shortage of construction materials and energy saving to be considered. It is obvious therefore that massive efforts are needed with the best of administrative and engineering inputs reinforced by long term political vision. A paradigm shift in engineering approach in terms of pre-fabricated building components, partially mechanised construction technologies, cost effective and sustained building materials and disaster resistant design will enable the more efficient use of scarce urban land high in consonance with the population densities specified in scientifically drafted master plans.

In each of the above cited basic realms of development targeted for sustainable living, the role of INAE will be to facilitate enhanced awareness on sustainable living, help governments evolve more comprehensive policy frameworks for implementation and devising ways and means of assisting academic and R&D institutions in putting their multidisciplinary engineering knowledge to such nationally challenging issues.

1.4 Water and Sanitation

Availability of and access to water of required quantity and quality is one of the chief elements of sustainable development. Water resources in India suffer from major spatial variations and this has given rise to demands for tempering such variations. The parameter for minimum availability of potable water is taken as 40 litres / capita / day through at least one pump for 250 persons within a distance of 1.6 km or 100 meter of elevation difference. The magnitude of social and technological problems in meeting this target in India is so great that robust engineering measures are urgently required. The remediation of water bodies from industrial pollution is still a major multidisciplinary engineering task with socio-political and economic challenges. Evolving appropriate policy framework and promoting trans-disciplinary networks for undertaking them on adequately scaled up level have been envisaged by the INAE. It is also a matter of great concern that the level of investment in sanitation is very low in India by minimum international standards. Rural sanitation coverage in 2008 was reported to be around 21% and no major Indian city is known to have a continuous potable water supply for drinking and sanitation purposes. The present state of water supply and sanitation has adverse impact on the public health as evidenced by nearly 80% deaths in poorer sections of Indian population occurring because of unsafe drinking water, inadequate sanitation and poor hygiene. Engineering solutions to these problems will be addressed by the INAE through a strong medicine-biology-engineering interface.

1.5 Energy

The current Indian energy scenario is very complex with the country heavily dependent on imported fossil fuels. Indian electricity market is the sixth largest in the world dependent primarily on coal, natural gas and hydroelectric resources. From technological perspective, the gas and oil production require highly specialized engineering expertise to exploit their full potential through secondary recovery options. India has sizeable renewable energy options in the form of solar, wind, hydro and biomass resources. High priority has accordingly being given by the government for their rapid development. India has to make a transition to low carbon energy economy at a sustainable speed. India has also been making significant progress in the nuclear energy field. The country is endowed with outstanding nuclear engineering expertise in pressurized heavy water, fast breeder and more advanced versions of reactors. The Indian power grid system is one of the most extensive in its geographical coverage.

From environmental considerations in general and climate change in particular, the phasing out of fossil fuels is gaining momentum in India. By 2037, the transition to low carbon energy technologies would have progressed to a reasonable extent. The transformation process will present several S&T challenges which require engineering ingenuity of high order to overcome them. The Indian energy scenario for 2012-2037 is highlighted in Sectoral Scenario 3. The INAE had taken several initiatives in the past for promoting the cause of Indian energy sector. The INAE vision on engineering of Indian energy systems covers a wide spectrum of activities including integration of knowledge, facilitating development of low cost energy systems, restructuring engineering education, measures to protect the intellectual property with high innovation content and enhancing research culture. The challenges include creation of substantial engineering knowledge base, improving the efficiency of energy end use systems and devices and development of sustainable hybrid energy systems leading to a smooth low carbon energy transition. The INAE currently hosts the CAETS Energy committed at international level and provides leadership to evolve viable options to achieve transition t low carbon economy.

1.6 Healthcare

The Indian healthcare sector, consisting of fully equipped government and corporate hospitals and attached medical colleges, medical infrastructure in thousands of medical centres established throughout the country, specialized medical diagnostic units and medical devices industry, will be around USD 160 billion by 2017. It provides unique opportunities as well as challenges to Indian engineers in terms of design, development and revamping of medical facilities and their automation, skill development in biomedical engineering areas and in product/process standardization activities. The future trends in Indian health care sector will be directed towards meeting the fast changing aspirations of its customers, insurance driven practices, revamping of existing medical facilities, emergence of wearable devices industry, high growth of state of art start-ups, further strengthening of medical tourism, rising trends in telemedicine and remote diagnosis and large scale private sector entry in medical education.

The INAE envisions the emergence of wearable devices sector, larger scale applications of innovative wireless, engineering and bio-sensors, big data, voice user interface and allied devices in Indian health sector by 2037. A proliferation of new start-ups and much greater convergence between medical, information technology and engineering professions is anticipated by 2037. The INAE is keen to evolve several mission mode initiative in this area.

2. SYSTEMS TO IMPROVE QUALITY OF LIFE

Foremost among the Indian challenges in this area must necessarily be met to ensure better quality of life for its people in terms of wealth creations built environment, quality of services and social belonging. India has a low global ranking in the Human Development Index (HDI) of the United Nations. It provides indirect measure of quality of life. Sustaining the continuing advancement of growing Indian population in various spheres of activity while still improving their quality of life is a multidimensional task embracing social, environmental and economic concerns. Its socio-economic dimension includes hard factors like infrastructure and consumer amenities and soft factors like systems for their efficient operationalization. It encompasses factors like clean working environment as specified by the well accepted biophysical parameters, the engineering quality of built environment, system reliability and efficiency, sustainable development and allied factors. Its economic dimension implies security of income, access to quality education, and new economic growth opportunities. Good governance of these systems contributes to improved quality of life.

2.1 Engineering Education

The Indian engineering education system has not kept pace with that of economic growth and rapid urbanization. Besides, India has still a sizeable illiterate population (26%). Serious efforts are being made to improve the situation with the government's resolve to provide education to all under the Right to Education Act. Engineering education cuts across most of the facets of social and economic development of the country. The efforts made since independence, both in the private as well as public sectors, had given rise to a huge expansion in engineering education sector. The private sector has been particularly active. The increase in capacity has been most noticeable since the decade of the 90s, rising almost 15 times. Also remarkable has been the growth in numbers of women entering engineering - almost 10 times in the last 40 years. Despite the rise in numbers of engineering college graduates, there is already a demand - supply gap that persists, borne out of the steeply increasing demand for engineers required for national development. Furthermore, quality remains a great concern, in particular as far as ability to perform for the growth of the industry. Contributing to this state of engineering education is also the deficient schooling system. Faculty shortage, and lack of competence, continue to constraint the system. As far as engineering education is concerned, India has entered the age of distributed intelligence in which knowledge has to be imparted to a wide cross section of its people. The vision of engineering education in the 21st Century will be predominantly based on an integrative approach in which analysis and synthesis have to be sensitive to societal needs and environmental fragility. Within this context, engineers have to shoulder highly challenging responsibilities and avail of the emerging global opportunities. An in-depth understanding of basic and social sciences is vital for inculcating critical thinking in various engineering disciplines. Universities and engineering institutions have to evolve more novel interactive mechanisms and partnerships with the student community for directing their creative knowledge to multiple real time application areas. Balance between social sciences, art and literature, economics, science and technology should prove to be a potent hybrid mix to create increasingly better skill sets to meet challenges. Another important aspect is discovering the right mix of improved technology and academic learning at different levels for different subjects of pursuit.

INAE proposes to assume greater participation in engineering educational quality improvement through mentoring the young faculty and the students and helping in continual evolution of the curricula and study material for the future generation of engineers to contribute more effectively to the socioeconomic development of Indian people. A prime need is to bring in greater flexibility to enable innovation. It is also imperative that the industry, academic and R&D organizations work together in a spirit of 'firm' hand-holding.

2.2 Innovation Driven Research

Creative engineering research contributes to the "innovation portfolio" of the nation. One of the recurrent negative statements about Indian engineering is the sparse publication record and also low patents. The Academy intends to be the torch bearer for taking engineering to the poor of the society, showing them the opportunities that beckon them - an enhanced "Patent Portfolio" will be an irresistible attraction in road shows, particularly targeted at the engineering researchers. This will be done in the mood of a crusade, but no compulsions, just focused promotion, in the interest of the people, of society, indeed of the nation.

The INAE is keen to sensitize Indian engineering community to pursue engineering research which is tuned to meet the quality of life enrichment demands of Indian population. The areas like low carbon energy, health care and disaster mitigation assume greater research relevance in the coming years. The most obvious research area for achieving environmental sustainability of products and processes of public importance is the discovery and development of eco-effective engineering designs for them at affordable cost. Intense global competition has to be faced by the Indian engineering community during their large scale deployment. Innovation has to be the hallmark of such research efforts.

2.3 Manufacturing

Indian manufacturing industry has made tremendous progress during the last 50 years and had been contributing significantly to the enhancement of the quality of life. Its share of global trade has been steadily increasing. However, its contribution to Indian GDP has been stagnating around 15-17% for the last several years. It is rather low for the Indian economy considering its size and global stature. A higher growth is imperative to create the projected 7-8 million new jobs each year outside of the agricultural sector. It is essential that the Government of India come up with a more proactive national manufacturing policy. A more conducive ecosystem needs to be created for boosting technology development and manufacturing excellence.

In order to realise the full growth potential of manufacturing by 2037, the country has to set for itself higher aspirational goals to be at the forefront of global manufacturing with its goals focussed on improved global share, higher levels of the value chain, international recognition of 'Made in India' brand and higher impact (25-30%) on Indian GDP, better employment record and inclusive growth in all regions of the country. The new technology domains include near net shape manufacturing, non-traditional manufacturing techniques, nanotechnology applications and micro factory concepts. Government's positive role is vital in growth-driven tax restructuring, R&D commercialization including technology incubation, revitalizing technical education as per industry's needs and modernization of labour laws with focus on skill enhancement. Industry has to contribute more significantly to the intellectual property generation and protection through strong government-industry-academia partnership. INAE is eager to facilitate (a) creative application of modern engineering concepts to the design of novel manufacturing processes (3D Printing, additive manufacturing, for example) and their automation / control, (b) sensitize the management of the Indian manufacturing industry to develop capabilities to compete in the global industrial ecosystem in advanced manufacturing including application of Big-Data with right scenarios leading to smart factory, environment surface, sustainable and manufacturing etc. and (c) a much more active role in enhancing the industry orientations of engineering education and research.

2.4 Electronics and Communications

Electronics and communications have emerged as powerful tools to empower human race to establish a knowledge driven society. Last three decades witnessed tremendous developments in nano scale electronics and systems on chip, photonics and optoelectronics, wireless and communication devices and allied areas. India provides a huge market for electronic components and assembled systems. The major elements of design ecosystem viz., EDA software support exists in the country. On the hardware front, Indian industry has, so far, not shown adequate dynamism in the semiconductor manufacture. The R&D base is fairly weak. The special incentive package from Government of India is now available for fab manufacture in India. New initiatives have to be taken by the Indian manufacturers in this sector.

The INAE is concerned about the lack of major industrial initiatives for the basic electronic hardware manufacture in India. On its part, efforts will be made by the Academy to sensitize the industry and the government to draw a mole balanced electronic technology roadmap for India, provide academic support and take promotional measures for semiconductor design, prototyping and manufacture and product development in microelectronics area. The Academy will also work with academic and research institutions in these areas to initiate or strengthen the hardware efforts.

2.5 Value Engineered Public Services

INAE realizes that the developing world is stepping into a completely unexplored and an uncertain era of 21st century. This is due to the rapid unsustainable growth achieved in several Asian countries, particularly China, and India amidst worsening environmental and energy scenarios. The extraordinary progress made in the developed world in multimodal transportation, information and communication engineering and automated healthcare has created a greater divide between rich and poor nations. These factors will make the enrichment of quality of life of Indian people in the future much more challenging than in the recent past. Innovative engineering breakthroughs have to be made and successfully applied on large scale to realise the legitimate dreams and expectations of the Indian people.

Value engineering of public services has a vital role to play in enhancing the effectiveness of public utility services considering the fact that several Indian cities are labouring under unaffordable service cost structure. The concepts of frugal engineering are most relevant for improving the functionality of Indian consumer durables. INAE proposes to take initiatives in creating appropriate knowledge hubs, to provide access to innovative thinkers in select areas and help in evolving and adopting new engineering networks comprising academics, non - governmental bodies and social entrepreneurs offering multiple perspectives. The Academy particularly strives to foster invention in university engineering education with reference to innovative public utility systems with enhanced efficiency. Successful Indian models in healthcare, societal services etc. will be examined and improved with precision, effectiveness and relevance in the coming decades.

3. MOBILITY AND CONNECTIVITY

Mobility and connectivity have direct influence on the growth of several socioeconomically vital sectors including industry food, healthcare, shelter and energy. The ability of people to reach quickly different locations for their professional, recreational, medical and domestic purposes is accordingly a fundamental requirement. The need for enhancement of their mobility is indisputable and will have to be widespread to positively influence all walks of life and professions.

INAE has recognized the paramount importance of mobility and connectivity to achieve equity in the Indian society. It will strive to enhance the spirit of curiosity on intelligent systems amongst young engineers, to sensitize the eminent engineers and institutions to explore and research the new frontiers of mobility and connectivity related knowledge and identify from time to time the intellectual and implementation barriers that block the entry of new engineering /technologies. Most obviously, the Academy proposes to sensitize the government to evolve forward-looking policies to remove formidable political and socio-economic obstacles. It is keen to establish an expert forum not just to convey the facts of engineering but also suggest the ways by which engineers acquire new knowledge through the tools of strong science-engineering interface. The forum will also focus on enhancing public understanding of mobility and connectivity engineering and importance of adopting new technologies.

3.1 Roadways

Road transport is most vital to the growth of Indian economy since it contributes nearly 5% of its GDP. The total length of national highway network is around 72,000 km in 2011 with 30,000 km of new highways being under planning and implementation phases. In addition, state highway and rural road networks provide the secondary and tertiary connectivity. According to a McKinsey (2010) report, India needs 2.5 billion km of roads and 7,400 km of subways by 2030. Indian road infrastructure needs huge public investment and has to be planned well in advance to make the right engineering choices for making it suitable for a multimodal transport system. The Indian society is constantly developing with increasing needs and complexity of road infrastructure is accordingly growing. The current Indian scenario, government and industry interventions, the demand and investment projections and safety aspects of Indian road systems are highlighted in sectoral scenario 7.

The INAE Vision 2037 on Indian roads reflects the future needs of Indian society with emphasis on sustainability, human safety during construction and use and multimodal user acceptability. The academy anticipates that the future road design and development technologies will cross the civil engineering boundary into physics, chemistry and other relevant sciences. Smart engineering concepts based on lifetime engineering are needed for fast, efficient and hindrance-free maintenance of Indian roads. The academy will make serious efforts to inspire and enable the Indian engineering profession to develop appropriate communication systems for the future Indian road users.

3.2 Railways

Indian Railways is one of the largest railway networks in the world (SS-8.1) comprising 115,000 km of track over a route of 65,000 km and 7,500 stations. It entered one billion tonne select club in freight movement joining Chinese, Russian and American railways. For faster and better organised connectivity by rail, the west and east dedicated freight corridors are being planned, and along these are expected to come a number of smart modern cities. These dedicated corridors will be unhindered by cross-movement of traffic. Another development of significance will be the high speed rail (HSR) facility envisaged along certain long routes .High speed movement is just not merely about reduction in travel time but an overall change of attitudes towards travel and its utility. In some sense, it is expected to have a profound influence somewhat similar to what modern telecommunications have had. The rapid multimodal transportation in urban centres in India has not made much headway. An attempt is being made to correct the situation by introducing metro-rail transport in Delhi, Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Jaipur, Kochi and other cities. This is a potential growth area for other urban centres in the future. Projection of Indian railway expansion and modernization is highlighted in SS-8.2. The INAE will strive to provide knowledge leadership in frontier rail technologies and evolve trans-disciplinary knowledge networks to execute study programmes on fast rail travel.

3.3 Waterways

India has an extensive network of inland waterway sources viz., rivers, canals, backwaters and creeks with total navigable length of 14,500 km. However, freight and passenger transport through this mode is highly underutilized. The total cargo moved by inland waterways is hardly 0.15% of the total inland traffic in India compared to more than 30% in Bangladesh. There are only 6 national inland waterways in India. Efficient and widespread inland water transportation (IWT) is vital for India to reduce congestion in other modes of freight and passenger transportation. The major constraints in the IWT development are diversion of large quantities of river water for irrigation, excessive silt loads on waterways, inadequate river conservancy measures and lack of adequate navigational aids and terminal facilities. All of them require novel engineering solutions for future development.

In recent years, Indian Merchant Shipping Act was amended to facilitate seamless integration of river-sea trade using coastal ships. In 2011, NTPC awarded a major contract for transporting 3 million tonnes per annum of imported coal to its power plants by waterway. Similar arrangement is expected for thermal power stations in Assam. India's first container transshipment terminal at Kochi is expected to boost coastal shipping. Even though, these are positive signs, much needs to be done by adopting novel engineering options to develop Indian IWT on global standards. India has been blessed with a coastline of 7500+ kms and Indian ports owe their existence to the projection afforded by natural bars and spits on the Indian coasts. Approximately 90% of Indian trade by volume and 70% by value is moved through maritime transport India is among the top 20 leading countries having large number of merchant fleets (1000+ ships) with 10.1 million gross tonnage hand by capacity. Indian shipping employs 35,000 officers and 110,000 seafarers. The modern day shipping involves ocean management, ports, logistics, ship building, supply chain management and ship management. Engineering staff provides the most crucial role in their management.

INAE has noted the need for rapid development of both inland water and sea transportation in India by 2037. Incremental short term solutions are not likely to contribute to their sustainable growth. Engineering challenges in this field mainly concerns maximization of transportation efficiency, new material development, structural design and improved propulsion systems and development of highly efficient, integrated and reliable transportation vehicles. Though shipping is a fuel efficient method of moving bulk freight, it is estimated to account for 3% of global carbon emissions. The academy has accordingly recognized the need for research on major maritime strategic frameworks viz., high efficiency hybrid drive systems, green retrofitting concepts, underwater noise suppression use of smart materials and structures, online corrosion and fatigue monitoring, robotic testing and inspections of vessels, intelligent communication networks for unmanned navigation and allied areas.

3.4 Airways

In recent years, India has witnessed unprecedented growth in air traffic and this trend will continue. Indian aviation market will become world's third largest after US and China by 2020. The current annual passenger load is162 million. The civil air transport was ushered in India as early as 1932 by Late JRD Tata. Tremendous growth was recorded in India in civil aviation after the independence and particularly during the first decade of the 21st century. In recent years, excellent infrastructure facilities have been provided to major airports in India leading to enormous opportunities for airlines, aircraft manufacturers and engineering service providers to develop their commercial activities. Many private companies have entered the fray in the manufacture / assembly and maintenance transport aircrafts. Several overseas multinational organisations are making India a preferred destination for setting up design, manufacture and knowledge intensive service centres in collaboration with Indian agencies. For the first time, India has successfully flight tested light combat aircraft (LCA) and will be going into production phase shortly. An advanced light helicopter (ALH) is already in production and is entering the export market. The design, development and manufacture of aircraft call for multidisciplinary aerospace engineering knowledge of high order. With the access to new knowledge on MEMS, material and nanotechnologies, composite materials, intelligent devices and modelling and simulation platforms, India is well placed to design, develop and manufacture 150 seat passenger aircraft in the foreseeable future.

The INAE envisions that the Indian aerospace industry acquires state - of - art capabilities to build hypersonic aircraft and develop morphing airframes to enable aircraft to fly like birds flapping their wings. The academy proposes to contribute intellectual inputs to establish much stronger education and research base in aerospace and allied engineering fields. The Indian aerospace and allied engineering specialists have to play a lead role in aircraft engineering, airport design and air traffic management. The academy will play an inspirational role in these endeavours.

3.5 Intermodal Transportation

The overall Indian transportation demand by all modes of transport for passenger and freight is likely to double by 2037.There is a strong need to develop intermodal transportation system that could maximize passenger convenience and h improve mobility with seamless transition among land, water and aerospace domains. The modern technologies for gathering, storing, processing, managing, reusing and communicating information through temporal, geographical, environmental and situational modes have to be employed for design of such systems.

The INAE envisions that the Indian engineering community facing and overcoming successfully, engineering challenges in intermodal transportation for ensuring highest seamless mobility for Indian population with minimum environmental damage. The academy proposes to sensitize the government and other stakeholders to promote academic and applied research on new materials, structural design, efficient propulsion system with low carbon fuels and development of highly efficient, intelligent and reliable transportation vehicles for intermodal transportation. Special efforts will be made to develop modern engineering curricula for undergraduate and post-graduate courses to cover this field.

3.6 Mobile Phones

Though mobile phones entered India as late as 1995, its market has achieved significant growth to reach 221.6 million units in 2012. The smart phone sales is growing at 35+% per annum. India's mobile value added solution (MVAS) market is expected to become double to USD 9.5 billion by 2015. The government is setting up National Optical Fibre Network (NOFN) to provide broad band connectivity to 250,000 village self-governing bodies. A recent study has shown that big data is the key differentiator for achieving customer-centric business culture in India. The INAE shares this vision.

3.7 Automobiles

The Indian automotive sector is one of the larger markets in the world and is also one of the fastest growing. Due to its strong forward and backward linkages with key segments of the Indian economy, this sector has a strong multiplier effect. This industry is also a significant employer. The passenger car and commercial vehicle segment is the sixth largest in the world with an annual production touching 4 million units in 2012, and the two and three wheeler market share registered a good growth. In tune with international emission levels, Government of India has prescribed the automobile vehicle emission standards. Interestingly, Indian automobile sector has been able to restructure itself, absorb latest technologies, effectively align itself to global markets and realize its true potential much better than many other sectors. Engineering has played a key role in placing Indian automotive industry on a high pedestal. There are some areas of concerns too in Indian automobile industry in terms of spiraling fuel costs, slow supporting infrastructure development (for e.g., roads) which have not kept pace with the growth of the automobile sector, high taxation, slow progress made in goods and service tax amendments and lack of well engineered disposal systems for used automobiles. The INAE will strive to provide leadership in frontier engineering knowledge relevant to the Indian automotive sector.

In terms of mobility and connectivity, the current situation in automobile sector in India can be termed as operating below its true potential in all sub-sectors except for a few. High regional imbalances and slow new technology entry are greatest barriers for further growth. The major challenge for India is to keep pace with the fast growing countries in the world in terms of speed of engineering and technology applications. Another constraint is the slower rate of economic growth as has been the recent experience and the overall challenge of finding the required investment. Further, the overriding problem will continue to be the acute shortage of skilled manpower, particularly to build modern infrastructure for enhanced connectivity and mobility. The INAE envisions the following for 2037:

- Minimizing digital divide to make connectivity affordable even to remote regions with high development potentials
- Smart power grids driven by intelligent collection and distribution systems for intermittent renewable energy.
- Increased reliability, security, inter-operability and profitability of multimodal transport and communication systems.
- Prompt removal of uncertainties in the development of major supporting infrastructure projects to minimize major implementation delays
- Special focus on intelligent systems to enable smarter services and seamless communication and transport links.

These challenges need to be addressed holistically by the INAE fellowship from different disciplines employing modern tools of product engineering, smart connectivity technologies and intelligent logistics to support the infrastructure development.

3.8 Space

The successful launch of its first satellite in 1980 through a launch pad in a coconut plantation in Kerala provided the impetus to India's space programme. The operationalization of polar and geostationary launch systems enabled India to possess one of the largest constellation of remote sensing satellites in the world to provide space based data for agriculture, water resources, urban development, mineral prospecting, ocean resources and disaster management. India is self reliant today in space technology and is capable of offering globally competitive launch services to 12 developed nations earning USD 2.2 billion through its commercial arm (ANTRIX). India successfully sent Chandrayan spacecraft to moon in November 2008 to become the 4th country in the world to do so. India's 100th space mission took place in 2012 to place French and Japanese satellites into the space. India has become the first Asian Country in November 2013 to launch a spacecraft to Mars. Interestingly, instead of directly flying to Mars, the 350 tonne spacecraft will orbit earth nearly a month to build up the necessary speed to sling shot its way out of earth's gravitational pull to embark on its 400 million km journey.

In terms of utilization of space technology, the ISRO has taken several initiatives, the most notable being the establishment of the Indian Regional Navigation Satellite System (IRNSS) to provide GPS information to India and other countries in the region extending up to 1500 km from its boundary. Several Indian companies have the necessary expertise to undertake sophisticated technology required for space systems. India has been participating in major international assignments involving United Nations (UN), Committee On Space Research (COSPAR), Committee on Earth Observation Satellites (CEOS) and others. In terms of human resource development, India has established Institute of Space Technology (IIST) to offer a wide range of undergraduate, post-graduate, doctoral research and overseas training programmes. INSAT/GSAT satellites support tele-education programmes of ISRO to provide distance education, digital interactive class rooms, multimedia and nonformal school and college education courses in India. The space based data are provided for Indian agriculture, water resource management, urban development, mineral prospecting, environment monitoring, forestry preservation, drought and flood forecasting, ocean resource exploration and major disaster management programmes.

Electrical, mechanical, electronics, information, communication, chemical and other branches of engineering are enablers behind space exploration, satellite navigation and telecommunication networking. These also provide competence in computing satellite pathways and engineering of new space vehicles and launching systems. Engineering mathematics is at the core of data processing and analysis and spacecraft orbital calculations.

The INAE envisions a highly challenging role for Indian engineering sciences in novel rocket propellant development, cryogenic engine design, evolving new range of composite materials, biomedical engineering of space health care systems and design of novel spacecrafts for manned space explorations. The academy proposes to play a pivotal role in sensitizing and supporting academic and research institutions through transdisciplinary links with ISRO to take the Indian space engineering to still higher level of academic excellence in the coming years. Research contributions are anticipated in the analysis of interplanetary space environment, in situ sensing instrumentation, big data analysis, dynamics of space power systems, microgravity effects, and novel biomedical devices. The academy also proposes to prepare bright young engineers to take up exciting leadership positions in aerospace system engineering and space business management.

3.9 Deep Seas

Deep Seas (3000+ft below) is the darkest region of the ocean where sunlight does not reach and plants cannot grow. It covers more than half of the planet earth and encompasses nearly 98% by volume of all living space on earth. The harsh and extreme conditions (pressure, corrosive salt water and freezing temperature) make deep sea exploration for minerals and energy one of the outstanding engineering challenges in terms of remotely operated tools / techniques and vehicles and communication systems.

Gold, cobalt, nickel, copper, manganese and rare earth metal crusts of sizeable thickness have been found in deep seas and international data bases exist on their size and locations. Shallow submarine mining is one of the preferred techniques. To facilitate deep sea mining, International Seabed Authority was established and 17 contracts have already been entered into for exploration of polymetallic nodules. Their exploration in the deep sea provides an exciting future opportunities for mineral exploitation. Engineering challenges lie in development of new equipment for deep sea mineral mining. Mapping of these resources itself is a challenging task. Another interesting area is the hydrothermal vents at the ocean crust which can act as gigantic batteries for energy generation.

The depletion of resources on land together with an increase in resource demand have motivated several countries in the world to attempt deep sea exploration for minerals. Indian engineers oceanographers and have been participating in most of the international explorations in the Indian Ocean as well as in Antarctica. India's interest extends to both harvesting and post-harvesting technologies and their application within Exclusive Economic Zone (EEZ). The INAE is keen that India is on the forefront of international efforts in deep sea exploration of mineral and energy resources.

4. SAFETY AND SECURITY

History has shown that India is prone to national and manmade disasters quite frequently. It is generally felt that the country is not adequately equipped to tackle these effectively. The Government of India has established the National Disaster Management Agency (NDMA) to devise measures for prevention, minimization and rehabilitation in case of national calamities. The natural disasters like floods, tsunami, cyclones, earthquakes, droughts etc., pose major threats to India. The country requires much more robust and technology backed timely warning systems and effective disaster mitigation measures in place. In case of manmade disasters, scientific and engineering analysis of such occurrences, their consequences and emergency situations are being assessed through computer aided hazard and risk analysis in India. Much more needs to done through the application of advanced science and engineering tools to achieve further risk reduction in natural and manmade disasters and in evolving fail proof response systems .Engineering research through remotely sensed data analysis, hazard and consequence modelling, information mining/ analysis and structural design engineering is vital for developing modern disaster mitigation tools. Detecting emergency threats due to disease outbreaks through big data mining and monitoring is vital for the Indian society, INAE proposes to work with NDMA and other scientific agencies to mitigate natural and manmade disasters in India in the future. The focus will be to enhance our ability for fast detection of disaster onset, pre-assess the hazard potential of various types of events, risk reduction through a strong science - engineering interface and strengthen Indian engineering capabilities in customizing the definitive designs to meet external and internal threats associated with major disasters.

Cyberspace information is a national asset and needs to be protected at all costs. Cyber threat is advancing faster than our efforts to cope up with its management. Engineering has played a major role in evolving cryptographic, firewall, microkernel and other techniques to ensure data protection. In future, coordinated efforts are needed in devising more robust cyber protection systems, better cyber security standards and certification systems. Indian Engineering capabilities in information and network security, disaster recovery and end user education have to be upgraded to face the challenges unpredictable due to constantly evolving nature of cyber risks. INAE can play an important role in facilitating science/engineering analysis of cyber disruptions and countermeasures, enhancing public awareness of cyber crimes and execution of projects with concerned academic and research institutes to recommend measures to be implemented at national level.

India is one of the vulnerable countries in the world as far as terrorism is concerned. Although country has come a long way in countering terrorism, still it is not free from major threats. Our major infrastructures are vulnerable to local disruptions which may lead to widespread failures. Terrorism is also gaining from science and technology in terms of employing sophisticated methodologies by the terrorists. However, science and technology alone can play a vital role in evolving counter terrorism measures for threats emanating from conventional weapons, chemical, biological and nuclear aided attacks. The engineering research and design opportunities are tremendous in areas like developing effective countermeasures for attacks on electric power grids and information / data systems and design/development of emergency response tools, blast / fire resistant buildings and structures, online surveillance systems, air filter for chemicals and pathogens and decontamination systems. INAE proposes to work with national bodies like Defence Research and Development Organisation (DRDO), Department of Atomic Energy (DAE), Department of Space (DOS), Council of Scientific and Industrial Research (CSIR) and Department of Science and Technology (DST) in facilitating new knowledge development in counter terrorism measures.

SECTORAL SCENARIO

SS1 : FOOD AND AGRICULTURE

1.1 PREAMBLE

Global agriculture (food, non-food crop and livestock) has been growing at rates of 2.1 to 2.3% per annum in the last four decades; in the developing countries growth rate was higher (3.4 to 3.8% per annum). The future may see some drastic decline in the growth of aggregate world production, to 1.5% per annum in the next three decades. In contrast, developing countries may experience some acceleration.

1.2 INDIAN SCENARIO

India has a strong agriculture base and it is currently producing enough to feed its people. The demand and supply data indicate that there would not be deficit for foodgrains, particularly cereals. In the case of pulses and oilseeds, the projections indicate that the country would have to depend on imports.

The state of Indian agriculture is as follows:

Agriculture caters the needs of more than 17% of humans and 13% of world's cattle. Agriculture consumes 70% of all freshwater and more than 40% of the planet's solid surface. India has only 2.3% of world's land and 4.2% of world's water. About 80% of our landmass is highly vulnerable to drought, floods and cyclones.

This sector contributes to 18% of GDP and supports 52% of our workforce.

Indian agriculture contributes to 8% global agricultural gross domestic product to support 18% of world population on only 9% of world's arable land and 2.3% of geographical area.

Agriculture contribution in the gross domestic product is declining in India. In 1990-91 it was 30 %. It declined to 15.7% in 2008-09.

Agricultural GDP increased at an annual rate of 3% between 1998 tom 2012.

India is the third largest agricultural producer, behind China and the United States.

India's current farmer income is 30-40% of its per capita income.

India's overall food consumption is expected to increase by 4 % per annum to reach Rs. 23 lakh crore in 2030 from 11 lakh crore in 2010.

The food and agriculture sector could potentially grow at 5.2 to 5.7% over the next 20 years. Such improvements are expected to improve farmer income by over four times.

During the last two decades, the average annual growth of agriculture sector was around 3% of the overall average growth of the economy (6 - 7%).

The average size of the landholding in 1970-71 was 2.30 ha. It declined to 1.32 ha in 2000-01. If this trend continues, the average size of holding in India would be mere 0.68 ha in 2020, and would be further reduced to a low of 0.32 ha in 2030.

Annually, India is losing nearly 0.8 million tonnes of nitrogen, 1.8 million tonnes of phosphorus and 26.3 million tonnes of potassium.

The water-table is lowering steeply in most of the irrigated areas, and water quality is also deteriorating, due to leaching of salts and other pollutants.

Demand for foodgrains would increase from 192 million tonnes in 2000 to 345 million tonnes in 2030.

Demand for milk and milk products would increase from 64 million tonnes in 2000 to 166 million tonnes in 2020.

Demand for fruits and vegetables would increase from 48 million tonnes in 2000 to 113 million tonnes in 2020.

India is one of the largest producers of oilseeds in the world but it imports around 55 to 60 % of domestic edible oil consumption requirements.

The average per capita food consumption of the developing countries rose from 2110 kcal/person/day 30 years ago to the present 2650 kcal. It may rise further to 2960 kcal in the next 30 years.

1.3 PROJECTED SCENARIO

Various questions that the sector is going to face in the coming decades, as outlined in a FAO report, include: How are the evolution of demand and supply in the next decades going to shape agricultural markets? How are long-term growth prospects and the expected evolution of per capita income going to affect agriculture and food production? Are the available land and water sufficient to feed a growing population? What role can economic incentives and technical change play in shaping supply? What are the priority areas where investment and research should be directed? How would the use of agricultural products in biofuel production affect markets? How can climate change affect production possibilities and markets?

The projections suggests that we need to strengthen significantly our agriculture base.

The world food production will have to double to keep pace with the population growth. It will be possible to feed the world's nine billion people in 2037 at an acceptable cost provided everything from high-tech seeds to low-tech farming practices is in place. The task will be easier if extra land is brought in, more fertilisers and pesticides are available, agriculture output is less dependent on climate change, and scarce ground water doesn't deplete that fast. Some of these provisions are impractical. “The world's future need for food depends not just on crops, however cleverly they are engineered — the ecosystems to support them must have a future too” is how experts see it.

The real challenge is to expand agricultural output in the limited land available for this purpose. The challenge can be met by developing high yielding new crop varieties that use less water, fertiliser and other inputs. It means developing drought and heat-resistant crops.

The agricultural practices have undergone major changes in the recent past. The knowledge intensive innovations have moved agriculture from 'cross breeding and hybridisation' to more precise and selective 'single gene transgenic' stage. These developments have brought in many new opportunities for the farmers. Besides developments in the conventional areas like developing plants which will not require external fungicide for their protection from pests and diseases, agricultural scientists and engineers are working on methods to improve photosynthetic efficiency. They are also working on developing plants with altered plant metabolism for better accumulation of the desired products. Another area which is getting the attention of scientists is to better understand the role of nitrogen fixing bacteria in order to capture atmospheric nitrogen.

An area that will need greater attention is `precision' agriculture based on remote sensing and global positioning. Precision agriculture is "planting the right seed in the right place depending on the field conditions or having the precise application of pesticides, nitrogen fertiliser or other inputs."

To meet the challenges of this sector, we need both aboveground and underground revolution. Researchers see in roots the second green revolution. Perhaps 'smarter roots' can provide solution to the problems of hunger.

In spite of the fact that India is becoming more and more self-sufficient in food production, the data indicate a general decline in the growth rate of technology, irrigated area, public and private investment, and NPK use. The growth rate in the agricultural credit sector, however, is increasing. The decline is due to various reasons. These are limited net sown area, depletion of soil fertility, water logging, fall in the level of the ground water table, disparities in productivity across regions and crops and increase in rain-fed and irrigated areas, decline in per capita land availability and shrinking of farm size, land used for going for non-agriculture use, etc. Due to these factors farming is becoming a non-viable activity.

Fresh water and top soil are major worries. We want crops that have much better water-utilisation efficiency. We need to develop crops having greater tolerance to drought-like conditions, by breeding or genetic engineering. The benefits are expected from the dissemination and adoption of conservation tillage and reduced tillage methods. Drought tolerance, nitrogen use efficiency, and herbicide-tolerant crops shall continue to get priority among scientists.

Both investment and efficiency in use of water are needed. Investment in irrigation, watershed development, and water conservation by the community are needed by way of water management. One of the prime requirements is to fill the knowledge gap in the existing technology.

While the dairy segment has been one of India's success stories, sustaining production growth will require significant investments to ensure that the sector meets demand requirements by 2025. In addition, substantial gaps in availability of livestock feed supply and competition for acreage from food crops pose fundamental threats to necessary dairy production.

The trend towards increased food consumption per capita will continue. The demand for high-value commodities (such as horticulture, dairy, livestock and fish) is increasing faster than foodgrains. These commodities are all perishable and require different infrastructure for handling, storage value-addition, processing and marketing. Projections indicate the need for increase in availability of non-cereal food. It should, however, be noted that, in terms of non-cereal food like fruits, vegetables, milk, meat and fish, India has not achieved self-sufficiency in terms of per capita availability. This represents a huge investment opportunity across the food chain.

While fruits and vegetables, meat and poultry segments have seen rapid growth over the last two decades, this is expected to stagnate with increased competition for usable land. In addition, the threat of the more lucrative export markets could also divert food supply away from domestic food availability, or more critically, land away from segments such as food grains, edible oils and dairy products, which run the risk of shortage by 2025.

Producing enough food for increased demand against the background of changing climate scenario is a challenging task for agricultural research. Developments in molecular biology, biotechnology, nanotechnology, information technology and geo-spatial technology are expected to provide significant new opportunities for productivity enhancement. These developments are also posing new challenges of capacity-building and human resource development. Massive efforts are needed to improve agriculture infrastructure. According to FAO estimates, to meet the challenge, investment throughout the agricultural chain in the developing world must double.

Growing energy crisis is a serious concern for agriculture sector and also for food security. Efficient management of energy in agriculture for various operations is the key research and development challenge. To efficiently manage energy, new sources of renewable energy need to be explored. This includes producing biofuels (such as ethanol) from non-edible feedstocks that can grow on low-productive areas and producing high-quality animal feeds from crop residues and waste from food-processing industries.

Our food consumption pattern is continually changing. Due to changes in consumption patterns, demand for fruits, vegetables, dairy, meat, poultry, and fisheries has been increasing. India is self-sufficient in cereals but deficit in pulses and oilseeds. India needs to alleviate the problems of malnutrition. The malnutrition problem is much broader than that of access to food.

Wastage of grains is a big issue; between one-quarter and one-third of the food produced worldwide is lost or spoiled. A recent report says that millions of tonnes of wheat and rice are at risk of rotting in India due to poor and insufficient storage facilities. Better planning and implementation of storage facilities to curb the wastage needs serious consideration of all concerned.

Food processing industry connects the two vital linkages – agriculture and industry. According to one estimate, the turnover of the total food market is approximately Rs.250,000 crores, out of which value-added food products comprise Rs.80,000 crores. This sector is expected to attract phenomenal investment (capital, human, technological and financial) in the near future.

Much is, however, needed to improve the performance of this sector. It needs to deal with the post-harvest losses. According to the estimates, post-harvest losses of selected fruits and vegetables in our country are in the tune of 25 to 30%. Limited organized presence and poor infrastructure in the procurement and supply chain are leading to wastage, unnecessary price-buildup and poor food quality and safety. Lack of scale and modern technology limiting nutritional impact and value-add in the processing stage. A three-pronged strategy has been suggested to reduce post-harvest losses— (i) compress supply-chain by linking directly producers and markets; (ii) promote processing of food commodities in production catchments to add value before being marketed; and (iii) develop small-scale processing refrigerated chambers or cold storages using conventional and non-conventional sources.

Health food and health food supplements are other rapidly rising segments of this industry.

To make India a global powerhouse in the food and agriculture sector, interventions suggested by CII include : accelerate sustainable yield improvements, promote win-win farmer-industry interaction, scale-up food processing and exports, invest selectively in infrastructure with private participation, nurture the next generation of agribusinesses, technocrats and entrepreneurs.

To meet the challenges of this sector, we need to evolve a multi-disciplinary approach involving biologists, agronomists, engineers, ecologists, policy makers, social scientists and farmers.

1.4 CONCLUSION AND INAE VISION

- The productivity of agriculture is low in our country. One of the reasons is small land holdings of small formers. Accordingly, agriculture also needs to be taken up on 'co-operative' mode (like Amul milk) or by private industry. The demand for food will shift away from cereals and pulses towards fruits, vegetables, and dairy products i.e. high value foods and complex proteins.
- Lack of raw material suitable for food processing, to give the desired quality of the end product, is one of the reasons for the growth of food processing industry slower than expected.
- Contract forming by private industry with buy-back guarantee, provision for seeds to give the desired characteristics to the agricultural produce etc. will significantly improve the situation.
- Mobile food processing units will reduce the losses to the farmers during glut season and will help in moderating the prices in the lean season.
- Health and wellness foods are the current trend with huge potential. In fact, Indian traditional foods, which vary in ingredients and taste depending on the region (as per Mother Nature), are time tested health and wellness foods. They need to be promoted both with standardization of process technology and machinery development for achieving uniform quality under hygienic conditions.

The Academy is best positioned to mediate interactions between farmers, policy makers, industry, agri- R & D units.

The endeavor of the Academy should be to focus on smooth connections between production and the social institutions of production - agriculture and agrarian, to ensure holistic development while the satisfying the increasing demands of society.

Efficient market access to agricultural products, going beyond transportation and reaching into storage of perishables is also a concern of technology and INAE will drive the efforts.

The Academy will work in coordination with other agencies of the government towards enhancing crop productivity, irrigation access, efficient use of water and fertilizer to foreclose the possibilities of food scarcity. In a similar vein, it will also interact with agri-processing industries to ensure technologically most effective value addition to agri-products that also enhances the profitability in agriculture.

SS2 : HABITAT

2.1 PREAMBLE

In the present scenario, it is felt that there is a need to create safe, secure and affordable habitat for the masses for the growth and development of the country, resulting in a more inclusive society. The literal meaning of 'Habitat' is the area or natural environment in which living population normally lives. A habitat is made up of physical factors such as soil, moisture, range of temperature, and availability of light as well as biotic factors such as the availability of food and the presence of predators (Source: Wikipedia). Hence habitat encompasses a number of facilities, which include buildings, roads, sanitation, water supply, disposal systems etc., that are required to be created for the living of human population. Also, it is necessary to create facilities from where the population living in the habitat can get their food and other requisites for their livelihood. One of the important necessities of mankind has been the habitat comprising of shelters including physical and social infrastructure, which provide a decent living overcoming all the adversities of natural hazards. The early civilisation has demonstrated the use of locally available material such as stones, wood and others for the construction of shelters. To match the ecosystem, most of the civilisations grew along the bank of rivers in plain areas and on high lands. As the civilisation has grown, the demand for more congenial habitats has grown tremendously.

There is an upsurge of rural people migrating to the urban areas for their livelihood, better education and better facilities and comfort. However, this has put an enormous pressure on the urban system, for which the urban areas were not geared up and as a result the requirement for urban facilities has increased manifold. However, with the passage of time as population continued to grow with better quality of life the search for more comfort levels intensified. The newer materials and construction technologies were employed using the natural resources which helped in constructing safer and durable building structures but at the same time de-stabilized the eco-system. The rapid urbanization, industrialization and population explosion are all attributed towards this switch over from traditional sustainable building practices to brick, cement, and steel structures, which are not so sustainable.

2.2 GLOBAL AND NATIONAL SCENARIO

2.2.1 Global Habitat Scenario

In 2007, the global urban population for the first time equalled rural population i.e. 3.3. billion. It is expected to reach almost 5 billion by 2030 with an annual growth rate exceeding 1.75%. This is almost twice the growth rate of world's total population. The population of rural settlements is expected to contract after 2015 at an annual rate of -0.32%. The Europe and Americas experienced intense urbanization during the middle of 20th century. The trend has now shifted to the developing economies of Asia and Africa. As per UN-Habitat statistics, the annual growth rates are highest in sub-saharan Africa (4.6%) followed by South Eastern Asia (3.8%), Eastern Asia (3.4%), Western and Southern Asia (2.9%) and North Africa (2.5%). In contrast, the urban areas in developed countries are growing at 0.75% per annum. Latin America is the most urbanized region amongst the developing countries with 77% of its population (0.43 billion) living in cities. Asia has the largest urban population i.e., more than 1.5 billion people with 40% of its population urbanized. Asia and Africa will continue to dominate global urban growth through 2030.

The scale of environmental impact of urbanization is a cause for global concern in the coming decades. Rapid economic growth combined with inconsistant implementation of industrial emission standards and increased use of motor vehicle transportation started to show a negative impact on urban environment in several developing countries in Asia. To manage environmental, economic and sociopolitical sustainability in these countries require polycentric forms of governance, environment friendly legislation and its stricter implementation and a more rational approach to the planning and management of human settlements. In many urban areas of developed and developing worlds, intra-city inequalities have risen as the gap between the rich and poor has widened. The inequality has a direct bearing on the quality of human habitat. If the quality of housing and the existence of basic services are considered as criteria for standard of living, the slums in several cities represent the highest physical dimension of poverty. The degree of shelter deprivation in the slums depends on the access to water and sanitation, nondurable housing, insufficient living area and insecure tenure.

The success of global millennium development goals depends heavily on how well cities in developing countries perform in the future. Housing durability enhancement, reducing overcrowding in urban households, establishing safe drinking water, health care and sanitation systems and increasing the tenure security of settlements are the major challenges before the concerned national governments. Education and youth employment greatly contribute to intracity inequalities. Innovative engineering practices have an important role to play in enhancing the quality of human settlements in urban and rural areas of the developing world.

2.2.2 Indian Habitat Scenario

Rapid urbanisation is taking place in India. Though the bulk of the population might still remain in villages, the urban content is rising. The urban population of India is likely to grow from 285.3 million in 2001 to 360 million in 2010, 410 million in 2015, 468 million in 2020 and 533 million in 2025, as per the projections based on past trends. Studies project that by 2030, the total urban population of India will be 590 million i.e. 40 per cent of the Indian population would live in urban areas (Mckinsey report). From 2001 to 2011 the housing stock in urban India grew by 50% i.e.26 million.

The number of metropolitan cities with population of one million and above has increased from 35 in 2001 to 50 in 2011 and is expected to increase further to 87 by 2031. The expanding size of Indian cities will be created in many cases through a process of peripheral expansion with smaller municipalities and large villages surrounding the core city becoming part of the large metropolitan area. The urbanization trend is going to have fundamental impact on the politics, economics and social situation of the country. Critical issues that are required to be addressed include inadequacy of basic infrastructure such as roads, sanitation and drinking water systems, transport, affordable housing, and an increase in slums and squatters.

In order to increase quality of life and achieve comfort level in terms of power, accoustics, environment, water and waste disposal, the people invade the territories creating imbalance in land resources. High energy intensive materials based on finite natural resources have become the dominant construction materials rather than locally available materials like wood, stone, adobe etc. Safe, secure and adequate housing is a fundamental need of people. By investing in shelters, people, in particular the low-income groups accumulate equity that can then be used as collateral, making them more credit-

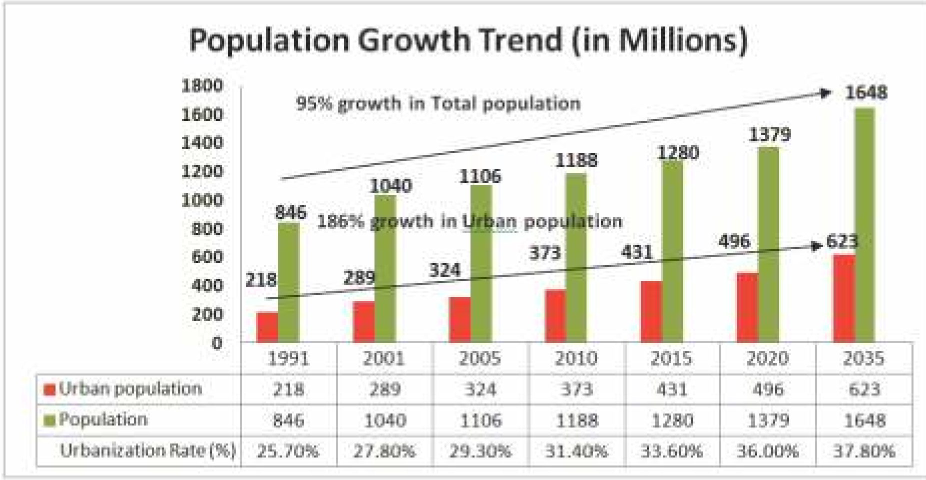


Fig. 1: Indian Population Growth Trend *(Source: rics.org/research)*

worthy for accessing finance through formal channels and also for generating income. Therefore, housing has always been and continues to have important socio-economic implications in India that determine the quality of life and welfare of people and places. Where houses are located, how well they are designed and built, and how well these are weaved into the environmental, social, cultural and economic fabric of communities are factors that, in a very real way, influence the daily lives of our people.

2.2.3 The Current Habitat - Status

As per the Census 2011, the number of households in India increased from 19.2 million in 2001 to 247 million in 2011. There has been considerable increase in the housing stock from 187 million in 2001 to 245 million in 2011, indicating a growth of 30.7%. Census 2011 also indicated that the gap between the households and housing stock has been reducing (Fig.2).

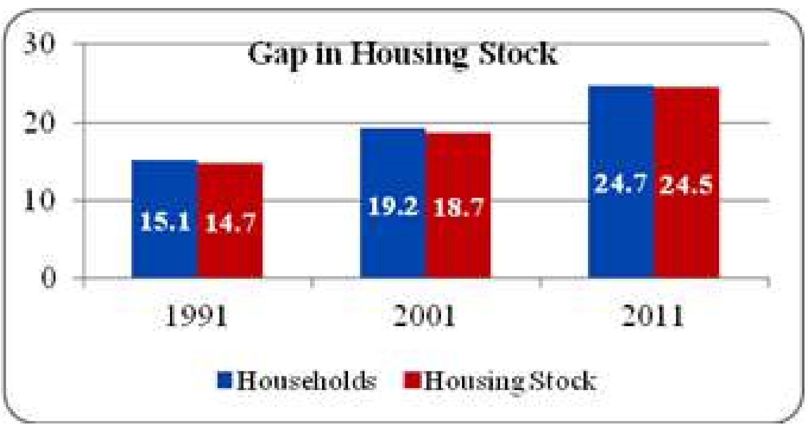


Fig. 2: Increment in Housing Stock

There has been a substantial improvement in the quality of housing stock. The country witnessed a decline of 16 per cent in households using grass / thatch /bamboo/ wood/ mud/tiles as roofing material. On the other hand, there has been a growth of 14 per cent in the proportion of households using metal / asbestos sheets and concrete as roofing material. Similarly, there was a decline of 9 per cent in the households using thatch/bamboo/ wood/ mud/tiles for construction of walls and an increase of 10 per cent in the households using burnt clay brick and stone for construction of walls. The rural-urban gap has reduced from 44 per cent in 2001 to 37 per cent in 2011. Approximately 86.6 per cent of the households live in their own housing stock and 11.1 per cent on rental basis (Table.1). The ownership pattern has remained almost constant in the last two decades, though the population has grown to 1.21 billion compared to 1.02 billion in 2001.

Table 1: Distribution of Households by Tenure - Status

(Figures in %)

Status	1991	2001	2011
Owned			
Total	86.3	86.7	86.6
Rural	94.6	94.4	94.7
Urban	63.1	66.8	69.2
Rented			
Total	11.8	10.5	11.1
Rural	4	3.6	3.4
Urban	34.1	28.5	27.5
Others			
Total	1.8	2.8	2.4
Rural	1.5	2.1	1.9
Urban	2.8	4.7	3.3

Around half of the households have drainage connectivity out of which two thirds have the open drainage and one-third has the closed drainage. Nearly, 47 per cent of the households have sanitation facility within premises out of which 36 per cent households have water closet and 9 per cent households have pit sanitation.

The data for accurate determination of the existing building stock in India is scarce. Similarly, no system as such exists to determine the building areas of being added to the existing stock every year. Different real estate and management agencies, research institutes and organizations bring out reports / articles with estimation of existing building stock or estimated area added to the existing building stock every year. There is a wide variation in the numbers estimated in these reports and there is no way to cross check the accuracy of these numbers as all the estimations are based on secondary data and different methodologies are used for arriving at these numbers. Table 2 gives existing building stock scenario.

Table 2: Existing Building Stock

Building Category	Area in 2011 (Million sq.m.)
Commercial	766
Residential	10,942
Total	11,708

Although the numbers from Census 2001 and 2011 show that the gap between household and housing stock is narrowing, the actual shortage of adequate housing is much higher. High rate of urbanisation and skyrocketing prices of land and real estate in urban areas have forced the economically weaker sections of the society to live in poor housing conditions (slums) characterized by congestion, dilapidated building structure, and lack of basic amenities. Thus, a wide gap between the demand and supply of housing currently exists, both in terms of quantity and quality in urban India. According to estimates of the Technical Group constituted by the Ministry of Housing and Urban Poverty Alleviation (MHUPA), the urban housing shortage in the country at the end of the 10th Five-Year Plan was estimated to be 24.71 million for 66.30 million households. The group further estimated that 88% of this shortage pertains to houses for Economically Weaker Sections (EWS) and another 11% for Lower-Income Groups (LIG).

For middle and high-income groups (MIG and HIG), the estimated shortage is only 0.04 million. During the 11th Five-Year Plan, the group estimated that the total housing requirement in Indian cities (including backlog) by end-2012 will be in the tune of 26.53 million dwelling units for 75.01 million households. If the current increase in backlog of housing is maintained, a minimum of 30 million additional houses will be required by 2020 (Mckinsey report). With current population growth rate, growing number of nuclear families, migration of people to urban centres, rising income levels, rapidly growing middle class, low interest rates and present housing shortage, the housing industry is set for a growth boom.

Housing shortage would not be a major problem if the mismatch between the people for whom the houses are built and those who need them is reduced. However, there is an increasing shortage of houses both in the urban and rural areas and the majority of the shortage pertains to the economically weaker sections and below poverty line people. Table.3 shows the expected shortfall scenario in housing during the 12th Five year plan period.

Table 3 : Urban Housing Shortage

Urban Housing Shortage as on 2012-2017		
Category	**Shortage in Millions**	**Percentage**
EWS	10.55	56.18
LIG	7.41	39.44
MIG	0.82	4.38
Total	**18.78**	**100.00**
Rural Housing Shortage 2012-17 as per 12th plan estimates		
Category	**Shortage in Millions**	**Percentage**
Below Poverty Line	39.30	90.00
Shortage other than above poverty line	4.367	10.00
Total	**43.67**	**100.00**

By the year 2030, India is expected to be the rising economic powerhouse. As per studies, India would grow to become the 3rd largest economy in the world in the next two decades. It is predicted and supported through credible arguments that India may even achieve a trend growth rate nearer to 12% or so, with certain conditions in place. In a report of the Royal Institution of Chartered Surveyors (RICS) on 'Real Estate and Construction Professionals in India by 2020- A demand and supply assessment of specialized skill-sets in built environment', an estimation of the demand for real estate space for various sectors has been made based on population growth estimation. As per these estimates, 4127 Million m2 of real estate space (which includes residential, retail, offices, hotels, healthcare and education sectors) is expected to be built from 2012 to 2020.

2.3 PROJECTED INDIAN SCENARIO FOR 2037

2.3.1 Residential Sector

According to the 2011 Census, the total housing stock of the country is 245 million for 247 million households and the housing stock in urban area is 78 million for 79 million urban households. As per numbers from census held in 2001 and 2011, there has been a growth of 50% in the number of Urban Housing Stock. By 2030, India will need up to 10 million new housing units per year for residential purposes.

One of the key challenges in housing is to promote organized rental housing in urban areas on account of projected increase in India's urban population from 377 million (31.2% share of total population) in 2011 to 600 million by 2030 (43% of total population). People in urban areas generally live in rental housing and this is the trend in other developed countries as well. With the expansion of IT, insurance and banking, health care, education, transport and other services and industry, nearly 70% of new jobs will be created in cities and most job seekers will be younger in age who would prefer to live in rental accommodation because of their mobility from one place to another in search of better opportunities and lack of affordability to own their own house / an apartment. Therefore, nearly 50 % of housing demand in urban centres has to be met through rental housing in the coming years. For achieving this, an appropriate policy, tax exemption, pro-rental housing laws and liberal finance for encouraging development of organized rental housing will be required. For large scale development, modern construction technology should be utilised to a great extent and this will play an important role.

2.3.2 Commercial Sector

Based on the data available from secondary sources, the existing stock of commercial buildings in India is estimated to be 766 Million Square metre. As per the report of the Royal Institution of Chartered Surveyors (RICS), 960 million m2 of commercial real estate space is expected to be built between 2012 and 2020, with growth in construction at an average of 107 Million square metre per year.

Table 4 : Existing and Projected Building Stock

	Existing Stock in 2011 (Million sqm)	Estimated Area in 2020 (Million sqm)	Building Stock in 2020, yet to be built
Health care	30	114	74%
Hospitality	70	450	81%
Offices	132	413	68%
Education	107	288	63%
Retail	346	378	8%

Note: Estimation of existing stock of commercial buildings has been made based on data available from secondary sources and is not a representation of the complete building stock in India. Estimated area of building stock in 2020 has been based on the estimations made in a report of the Royal Institution of Chartered Surveyors (RICS) on 'Real Estate and Construction Professionals in India by 2020.

Increased revenues of companies in the services business, especially in the software and IT services (ITES), as well as of IT-based business processes (BPO), have resulted in the recent growth in the office buildings. According to the estimate of a consultancy firm Jones Lang LaSalle, up to 70% of the demand for office space is driven by over 7,000 Indian IT and ITES firms, 15% is accounted for by financial service providers and the pharmaceutical sector, with the remaining 15% due to other sectors. Earlier commercial properties were concentrated mainly in the CBD (Central Business District) areas in large cities. However, with the emergence of IT-ITES, which has the requirement of large office space, commercial development started moving towards city suburbs. It resulted in multi fold development of city outskirts and suburbs. With influx of multinational companies (MNCs) and the growth of the services sector (telecom, financial services, IT & ITES, etc.), the demand for commercial office space is expected to grow further in the coming years.

2.3.3 Healthcare Sector

Availability of healthcare facilities in the country is expanding in a rapid pace. During the last few years there has been a great change in the availability of health care facilities in the country. As per the 11th Plan, number of government hospitals increased from 4571 in 2000 to 7663 in 2006, that is, an increase on 67.6%. Number of beds in these hospitals increased from 430,539 to 492,698 that is an increase of 14.4% and in 2010 total number of beds was 577,000. Government of India aims to develop India as a global healthcare hub. There has been a wide array of policy support in the form of reduction in excise duties and higher budget allocation for the healthcare sector. Due to increase in the levels of health awareness, growing disposable incomes, focus on medical tourism, lifestyle related diseases, there is going to be a strong demand for health care services in India. This will create requirement of greater investment in healthcare infrastructure and increase in the number of healthcare buildings in India.

2.3.4 Retail Sector

Growth in the organised retailing sector and entry of international retailers in India has led to an increase in the demand for modern retail space. With growth in the economy, rapid urbanization, rising income levels, availability of easy credit, brand consciousness, consumerism is growing in India. There is an increasing demand for high class shopping experience resulting in a surge of upcoming organized retail malls all over the country. Several shopping malls have come up in the last few years, initially in Tier I cities and then in Tier II and Tier III cities as well. As per a recent study, the organised retail real estate stock is expected to increase by more than double from 41million sq.ft. to 95 million sq.ft.

2.3.5 Hospitality Sector

Indian hospitality industry has witnessed a strong growth over the last few years due to favourable economic and political environment. Strong growth in tourism - domestic, business and leisure, has benefited the industry. India has also emerged as a medical tourism destination. According to a research by the World Travel & Tourism Council, travel and tourism in India is expected to grow at 12.7 per cent per annum until 2019. As per Ministry of Tourism statistics, the total estimated supply of hotel rooms is expected to reach 6.6 million in 2020.

2.3.6 Educational Sector

The education sector in India is considered as one of the major areas for investments as the entire education system is going through a process of overhaul. The country has 544 university level institutions, which includes 261 state universities, 73 state private universities, 42 central universities,130 deemed universities, 33 institutions of national importance and five institutions established under various state legislations. The country has around 79 centrally funded institutions, which includes 16 Indian Institutes of Technology (IITs), 11 Indian Institutes of Management (IIMs) and 30

National Institutes of Technology (NITs). According to the Ministry of Human Resource Development, by 2020, to increase the percentage of students going for higher education from the present 12.4% to 30% in the country, India will need 800 more universities and another 35,000 colleges.

Emerging out of the above situation, placed below are some relevant statistics:

1. 590 million people would live in cities by 2030 in India
2. 270 million people would be in working class
3. 91 million people would be in the middle class segment
4. 70 per cent of employment generated will be in cities
5. An increase of 40 per cent is expected in the urban population
6. Urban India will drive a fourfold increase in the per capita income of India
7. 38 million units housing shortage projected in 2030, a rise of around 13 million from 25 million housing demand in 2007.
8. $395 billion required as investment in affordable housing.
9. India requires 20 lakh units annually; however it manages to build less than 2 lakh dwelling units per year.
10. Annual outlay of around 150000 million rupees can help meet affordable housing shortage.
11. As per UN estimates, urban population is expected approximately 40 per cent of total population.
12. Increasing investment in urban infrastructure from 0.7 per cent of GDP in 2011-12 to 1.1 per cent by 2031-32.
13. Number of metropolitan cities with a population of above 1 million to go up to around 87 in the year 2031 from the current 50.
14. Cities with population of 5 million to double i.e. from 64 in 2011 to 128 in 2031.
15. Annual population growth to stabilise at 2.5 per cent during 2001-2031.
16. Five States are likely to be more than 50 per cent urbanized-Tamil Nadu, Gujarat, Maharashtra, Karnataka and Punjab.
17. The UN population projections estimate that the urban population of India will be larger than its rural population by 2045.
18. Cities will account for 70% of India's GDP in 2030.

2.4 INAE VISION

INAE is convinced that in order to improve the quality of life, it is of critical significance that the Indian housing stock is improved through urban renewal, in-situ slum improvement and development of new housing stock in existing cities as well as building new townships to cater to the need of the housing demand.

Housing demand is expected to be met through the building of new housing stock and integrated and planned townships, up gradation of existing housing stock and replacement of old dilapidated stock and redevelopment of slums.

While addressing the above aspects, the major issues required to be looked into are related to planning, material selection, technology and engineering designs, environmental regulations, life cycle assessment of habitual materials and disaster resistant systems. To address these issues, it will be essential to look into the policies, legislations to enforce use of locally available materials, legislation to minimise use of natural resources in conjunction with the development of alternate energy efficient affordable material and technology for effective implementation of the developments.

It is anticipated that in next two decades and half, more than 40% of the population will reside in urban sector. It is possibly the natural process and, therefore, the urban areas need to be fully geared up and equipped to take up this challenge of urbanization in terms of habitat. The densification of population into urban areas would call for better infrastructure including housing and basic amenities such as drinking water, sewerage, sanitation, drainage, roads, education and health. Due to large shortage of land in urban areas, the tall buildings will be the dominant urban forms. To reduce pressure on urban areas, it will be appropriate to develop facilities around rural areas so that the migration can be reduced. Also, it is believed that the road which leads the villages to the city, the same road may lead the cities to the rural areas. This reverse trend will be essential for future growth.

Considering the fact that a giant leap is essential to meet the challenges of intelligent sustainable habitat, the following are required:

- Mechanization in the construction sector and miniaturization of construction equipments for large usage.
- Use of prefabricated technology for efficient, sustainable quality products.
- Use of sensor technologies for smart and intelligent devices in the habitat sector for true intelligent building.
- Use of embedded technology to enhance the quality of construction technologies and supervision.
- Development of technologies by tapping alternative sources of energy for sustainable habitat like solar, BIPV, wind, thermal etc. and material alternatives such as coarse aggregates and sand etc.
- Use of control technologies to achieve disaster- resistant habitat system.
- Recycling of materials, especially waste material for useful products.
- Zero maintenance & preventive maintenance.
- Sustainable in terms of natural resources, waste minimization, environment degradation, ecological system, low energy, minimum life cycle cost and recyclable that should be in harmony with nature.
- Environment sustainability of urban development which seeks to make cities sustainable through improvement in energy demand and minimizing green house gas emissions.
- Quicker methods of construction and high performance materials.

All of them require engineering expertise of high order. INAE envisions an important role for itself in promoting innovative ideas on developing cost effective and sustainable habitat systems for rural and urban poor through intellectual interactions among the engineering community, encouraging research institutions to develop novel materials and technologies for housing and insensitizing the government on policy issues for effective implementation of safe, secure and affordable habitat in Indian cities and semiurban areas.

SS3 : ENERGY

3.1 PREAMBLE

The world's primary energy consumption is projected to grow by an average of 1.6 – 1.8% beyond 2010 adding more than 40% to the current global consumption by 2037. Most of the growth is expected in China, India, Brazil and other non OECD developing countries. Without a shift in the fuel mix, this growth is bound to exacerbate climate change considerations.

The economic development of above countries in recent years has created a high demand for energy that can be met only by expanding, on priority, the resource base of all fuels available with them to minimize the high import cost burden of overseas energy supplies on their economies. However, the fuel mix transition from nonrenewable to renewable type requires long gestation period in energy sector since the factors like its availability, cost effectiveness, technology adaptability and market acceptability are involved. Some developed countries, notably the US, are making efforts to utilize shale and tar sands as transitionary fossil fuels.

3.2 CURRENT INDIAN SCENARIO

The current Indian Energy Scenario looks quite complex with the country's heavy dependence on imported fossil fuels. To reduce its per capita carbon emissions, India has to turn increasingly to lower carbon and renewable energy resources on a long term basis. Statistically India has 15 crore rural and 6 crore urban households. Indian electricity market is the sixth largest in the world.

From technological perspective, the offshore gas and oil production including secondary oil recovery from depleted wells require greater engineering expertise to exploit full potential. Similar is the case with electric power from larger capacity nuclear reactors. India has sizeable renewable resources in solar, wind, hydro and biomass options. Government of India has been according high priority to developing these resources for electric power generation. High level engineering knowhow and expertise is required to achieve the goal. This is where INAE sees its contribution over the next couple of decades make an impact, by advocating systems and procedures that propel the nation towards renewables.

The Indian power grid is one of the most expensive power distribution systems in the world. Only recently its southern grid has been integrated with the others that cover the rest of the country. Engineering challenges are immense in minimizing the transmission losses and modernizing the powergrid system to handle electricity from renewable and fossil fuels.

25% of Indian population still has no access to electricity. The average size of the rural and urban households is 4.5. The primary cooking fuels for more than 80% of rural households are firewood, animal dung cakes and other agricultural residues, that are high GHG emitters and for 57% of urban households are LPG, kerosene, firewood and coal. Indian household consumed a total of INR 810 billion worth of fuel during 2004-05. Interestingly, household energy sources as well as the quality of concerned energy supply services have profound influence on quality of life, gender equality and social ladder of the people in India. Use of higher quality primary fuels has significant positive influence on social development factors.

On the Indian commercial energy front, the electrical power sector is a fast growing component (23% in 1990 to 38% in 2009). India has the third largest commercial energy demand after China and USA. India's energy demand has more than doubled from 320 million tonnes of oil equivalent (Mtoe) in 1990 to 669 Mtoe in 2009 with a low per capita consumption. India's largest primary energy source has been coal with a share of 42%, biomass at 25%, petrochemical crude at 24%, and natural gas at 7%.

India satisfies its electricity demand primarily from conventional thermal power generation with coal representing the lion's share (Fig.1). Nearly 83% of India's power generation capacity of about 154 GW per annum is handled by the public sector with the National Thermal Power Corporation Ltd. (NTPC) accounting for 20% of the country's capacity and the private sector accounting for less than 17%. These exclude captive generation power plants which contribute 19.5 GW. The per capita consumption was 704.2 KWh in 2007-08 against the world average of 2595.7 KWh. The Eleventh Five Year Plan had provided a turnaround for private power producers in India. While the energy availability was 689 TWh, the actual requirement was 774 TWh. Its peak power deficit is 12.1%, and overall energy deficit at 9.4%. It has been reported that Indians spend about $6.2 billion every year to fuel and maintain power back-up equipment to secure themselves against frequent outages.

3.2.1 Non-renewable Energy

During the Eleventh Plan, India had added 78.7 GW of power with 76% from coal-based and 20% from hydroelectric sources. India's increasing dependence on coal to meet electricity needs will continue well into the distant future with some projections pointing towards 70% of electricity generation from coal in 2030. However, most of these are expected to come from advanced coal technologies that aim at tapping coal with higher thermal efficiencies coupled with less adverse ecological impact. The advanced ultrasupercritical steam cycle calls for extensive indigenization of materials supply and component design-cum-fabrication capabilities, both of which should auger considerable business potential to Indian power sector. These are areas of high engineering challenges and fit in nicely with what the Academy can help promote..

3.2.1.1 *Coal*

Though India has large coal reserves (200 billion tonnes), it is typically with high ash content (30-45%) with calorific values in the range of 3,000-4,500 Kcal/kg; use of this coal for power generation is a major technological, environmental and economic challenge India has to import 90 million tons of coking coal in 2010 for blending and other applications in steel industry. The institutional framework for R&D is not very strong in the country to evolve clean coal technologies for the future application. Matching with the capacity expansion programme in the Indian power sector, the current level of coal production (370 million TPA) which is predominantly managed by the public sector needs to be stepped up in a graded fashion to achieve 1500 million TPA target set for 2030. [One needs to at least acknowledge the socio-environmental effects of such scaling up, to the tune of 8% CAGR]

From the engineering perspective, the current coal mining in India is limited to a depth of less than 300 m while 40% of its reserves are below this depth. Nearly 90% of coal mines in eastern India are open cast. Though less dangerous for its workforce, they contribute to ecosystem damage, soil erosion and deforestation. Underground coal mining has lesser environmental evils and higher potential to access deeper coal resources in the future. It requires advanced engineering knowledge and technology for underground mining beyond 300 m. This is an engineering challenge that needs to be solved in the near future.

The coal washing capacity created in the country is of the order of 240 million TPA. India's coal beneficiation capacity has remained at 135 million TPA. Coal India and its associates are taking action to set up new washeries (194 million TPA) for coking and non-coking coals with coal beneficiation as the prime target. A good deal of commercial success has been achieved in India in clean combustion technologies for coal. Indian power plants up to 500 MW capacity are based on pulverized coals (with 30^{+}% combustion efficiency). Major initiatives have been taken to adopt supercritical coal combustion technology with 55% efficiency in mega power plants with greater than 600 MW capacity. NTPC-BHEL joint initiative has been reported in the coal gasification with IGCC concept. The liquefaction of coal through FT synthesis of gasified coal is being investigated on pilot level in Indian R&D institutions. India requires a well-integrated engineering infrastructure for its coal supply chain including modern railroads, seaport coal handling systems and underground coal mining equipments seizeable amount of FDI is required for establishing them at a fast pace.

3.2.1.2 *Oil and Natural Gas*

India has 0.8 billion tonnes of petroleum reserves (0.3% of the world reserves) offshore production accounts for 53% of country's oil production. From engineering perspective, the offshore production terminals require high level engineering expertise to exploit their full potential. India's refining sector had undergone significant transformation beginning 2001 to attain 4.9 million barrels per day of refining capacity in 2012. India is being promoted as regional refining export hub.

The Indian oil and gas sector is relatively more open and competitive than other energy subsectors. It is open to 100% FDI. Its growth, however, is hampered on account of commercially pricing unattractive, underutilization of domestic resources and lack of external investments. In 2001, Government of India laid out a long term vision for oil and gas sector with the basic objective of achieving enhanced energy security and creating free market conditions within the country.

India's share of natural gas reserves is around 42 million cubic feet in 2011. Significant gas discoveries occurred in 2002 in the KG basin off India's east coast. Currently, 80% of India's gas production comes from offshore fields from the west coast. Onshore gas production is dominated by Assam, Gujarat, Tamilnadu and Andhra Pradesh. Gas imports accounted for 28% of Indian gas supply. It imports LNG through two terminals located off its western coast. Natural gas fuels about 10% of the total installed power generation capacity in India. The Eleventh Plan called for 7,313 MW alone of gas-based capacity addition, of which only 2,984 MW was commissioned by the end of June 2009 due to gas shortage from its gas fields.

3.2.1.3 *Nuclear*

India has envisaged a sustainable nuclear energy program which is based on three stages, with each stage propelling the growth of the subsequent ones. The first stage is based on energy generation from heavy water and pressurised heavy water type reactors the technology of which is sufficiently mastered by the Indian atomic energy establishment including the in-core Zircaloy based fuel assembly fabrication and heavy water production. The second stage revolves around fast breeder reactors employing the mixed oxide fuels with predominantly austenitic stainless steel based core materials. The signing of the Indo-U.S. nuclear deal in October 2006, following a waiver from the Nuclear Suppliers Group, has opened up new opportunities for India in civilian nuclear field. The Indian nuclear market is estimated to be worth $100 billion, plans are afoot to build 40,000 MW of nuclear capacity by 2020. Government of India is keen to enhance the nuclear power share in the overall fuel mix from 3% to 25%

by 2050. India has 17 pressurized heavy and 2 boiling water reactors with their total installed capacity at 4.54 GW which is equivalent to 3% of total installed power capacity in the country. Another 2.72 GW capacity nuclear power plants are under construction.

3.2.2 Renewable Energy

India has access to sizeable renewable resources viz., solar, hydro, biomass, and wind energy options. The legal, policy, and regulatory environments are also becoming more positive to enhance renewables share in the energy sector. As of March 31, 2010, nearly 17 GW of grid-connected renewable power was in place. Of this total, 11,807 MW was from wind energy with small hydropower projects providing 2,735 MW and bagasse-fueled cogeneration plant generating1,334 MW. Currently less than 20 MW solar energy generation capacity has been installed. Off-grid and distributed renewable-energy generation supplied an additional 404.56 MW electricity equivalent.

3.2.2.1 *Hydro Power*

The share of India's current hydropower generation capacity is around 20% and it share is likely to go down by 2030 due to the emergence of other renewable resource options. The Eleventh Plan has seen slippages of 5,200 MW capacity of hydro projects. Land-acquisition, resettlement and rehabilitation issues have caused significant delays in hydro projects. Mini- and micro-hydel projects with innovatively designed turbines offer good scope for further exploitation of this option for power generation. Their impact on ecosystem in hilly regions in our country need to be carefully examined from the experiences of recent unprecedented flood damage in Uttarakhand.

3.2.2.2 *Wind Power*

In terms of installed capacity of wind based generation, India ranks 5th in the world. Indian wind-turbine manufacturing company Suzlon is the largest in Asia in terms of its market share and has installed more than about half of the capacity in India. Future offers considerable scope for off-shore wind energy development potential with active policy and infrastructural support already in place.

3.2.2.3 *Solar*

The National Solar Mission, has set a goal of generating at least 10% of power in India from solar energy. It envisages increasing the production of solar photovoltaic panels to 1,000 MW from the current 235 MW per year and generating 1,000 MW of grid-connected solar power in 2017 up from the current level of 10 MW. In December 2009, the Government of India unveiled plans to achieve 20,000 MW of installed solar power capacity by 2022 under the Jawaharlal Nehru National Solar Mission for electrifying thousands of villages, create jobs, help combat climate change and achieve grid parity pricing by 2022. The target is set to be achieved in three phases.

3.2.2.4 *Geothermal*

Though the Indian potential is around 10 GW, no geothermal power plants were operating anywhere in the country till 2011. However, five projects with a combined capacity of 250^+ MW are being planned for implementation.

3.2.2.5 *Wave and Tidal*

No wave or tidal energy based power plants existed in India till 2011. However, four demonstration projects for wave and tidal energy utilization for power generation are in the planning phase.

3.2.2.6 *Combined Heat & Power Technologies*

The combined heat and power (CHP) concept revolves around bagasse-based cogeneration, largely in the sugar industry. India's CHP potential is estimated at 7,574 MW. With sugar sector expected to contribute, 5,000 MW. The IEA estimates that CHP potential will reach 27,800 MW in 2015 and 84,800 MW in 2030.

3.2.3 Electricity Distribution

The Indian power grid is one of the most extensive power distribution systems in the world. Its total transmission capacity is around 30 GM **[????]** at a voltage level of 110 KV. It covers more than 6.76 million kms of lines and over 282,000 MVA of distribution transformer capacity as of March 2008. It is expected to grow at 3-5% annually. Technologically the Restructured Accelerated Power Development and Reform Program (R- APDRP) of the Ministry of Power aims to reduce transmission losses to below 15%. Many urban areas have shown a decline in losses, but the situation in rural areas needs drastic improvement. Further strengthening of the national power grid is envisaged through high- capacity alternating current extra high voltage lines, 765-kV AC lines, and high- voltage direct-current lines.

3.2.4 Investment Scenario

India needs to add about 200 GW electricity in next seven years. This obviously entails huge investment, as much as an estimated INR 12700billion for power generation, INR 5,000 billion for transmission and INR 8,000 billion for distribution. Mechanical and materials industries have a major role to play in achieving these targets.

3.2.5 Energy Equipment Manufacturing Capabilities

Indian manufacturing sector has wide ranging engineering capabilities. India currently manufactures wind generators of $1{,}600^{+}$ kW per unit capacity. India has developed engineering expertise for designing, constructing, and operating small hydropower plants. India has manufacturing facilities for equipment and components used in solar PV systems, though there is a need for developing engineering expertise for establishing megawatt-scale PV power generating systems. A number of solar thermal applications have also been developed in India, which include water/air heating, cooking, drying of agricultural and food products, water purification, detoxification of wastes, cooling and refrigeration, heat for industrial processes, and electric power generation. Biomass based co-generation combustion technology based on atmospheric gasifiers, India has significant native experience and expertise.

3.2.2 Indian Energy Scenario in 2037

The 2006 integrated energy policy formulated by the Government of India projects a growth rate of 8% until 2031-32 to sustain the overall economic development. India's energy demand in 2030 is likely to be double that of current demand. The likely growth trends in major non-renewable and renewable feedstocks are highlighted in Fig.1.

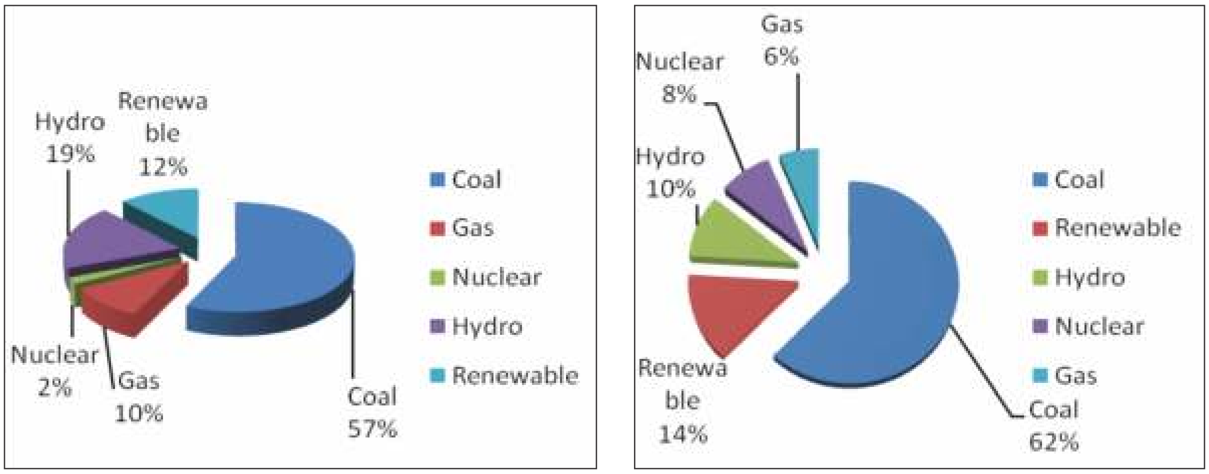


Fig.1: Anticipated Changes in Energy Mix Pattern for Power Generation in India (2011-2030) as per on school of thought

3.2.3 Non-Renewable Energy Growth Prospects

The current trend shows that the Indian energy sector has already entered the efficient energy utilization pathway. It is best for India to pursue high economic growth policies by simultaneously exploiting alternative energy options through improved and newly acquired technological capabilities.

The alternative scenarios include new thrust to enhance extractable coal reserves, technological upgrade of coal mining, strengthening coal R&D for cleaner processing, advanced engineering techniques for deep coal seam mining, reduce the consumption of petroleum products in transport sector by enhancing the share of public transportation, electrification of railways, enhanced freight share by railways, more rigorous auto pollution norms, use of cleaner fuels including ethanol blending and biodiesel, use of naphtha exclusively for petrochemical sector and employing natural gas predominantly for power generation, and fertilizer production. It is also to be noted that India's energy sector is administered through a complex multi-ministerial structure consisting of ministries of power, coal, petroleum and natural gas, new and renewable energy and atomic energy. The role of the ministry of Environment and Forests is to develop environmental policies. There is need to integrate their functions to evolve and implement long term sustainable energy policies with a single window monitoring system.

3.2.4 Coal

Coal will continue to remain India's most important source for electric power generation accounting for not less than 60% of energy mix under most of the development scenarios. This means, India needs coal at around 4 times of the current production level viz., 1.6 billion tonnes/annum after 2030. The main focus in the coming years has to be given to the following to achieve efficient and sustainable development of India coal sector to bring the country on to a reliable and cleaner energy path.

a) Faster introduction of deep seam underground mining through the acquisition of overseas advanced technologies to increase the production output much more rapidly and in a cleaner fashion.

b) The coal pricing based on its useful heat value has its own limitations in terms of coal producers to improve quality and production levels. India has to adopt the international practice of basing the gross calorific value to rationalize the price structure of imported and Indian produced coals.

c) The Indian coal characterization system for its classification is primarily based on geological evaluations without assessing the quality, mineability or extractiability of deposits. The INAE interactions with the experts of Canadian Academy of Engineering in December 2012 had identified the need to evolve an application oriented coal classification in India.

3.2.5 Oil and Gas

India will continue to be heavily import dependent on crude oil with its low reserves. Even though new oil discoveries may help the situation to some extent, the anticipated crude oil imports in 2030 is likely to be 6.85 million barrels / day (mbd) as against the current level of 2.5 – 3.0 mbd. The oil demand could decrease by about 17% in case of successful substitution with other feedstocks or could go up by 27% in case of no demand growth reduction.

Natural gas usage in India is expected to grow annually at 4.7% due to rising domestic production and imports. Industrial activity will account for 50% and the power sector for 29% of the gas consumption growth. The natural gas demand in India for power generation is projected to be 352 million metric standard cubic meters per day (MMSCMD) by 2030 for the electric power sector and around 85.6 MMSCMD for city gas supply. The expected increase in domestic production is from 13.6 MMTPA to 73 MMTPA in 2037 assuring all the existing planned gas terminals in India would materialize. Its availability through coal bed methane is not considered. India has a network of 13,000^{+}kms of natural gas transmission pipelines with a design capacity of around 330 MMSCMD and is expected to expand to 30,000^{+} kms by 2037 with a total design capacity of 730 MMSCMD.

3.3.4 Renewable Energy Prospects

It has been optimistically projected by the Green Peace International that India's 35% electricity demand will be met by the renewable energy by 2037. This is a huge opportunity area for Indian engineers. In the context of India's current economic constraints, the future investments in renewable technologies will be a win-win option since it provides reliable energy for 400 million people who have no access to the electricity today. While renewable energy currently accounts for 10% of total power generation capacity the wind power accounts for 11,000 MW. It has a potential of 48,000 MW by 2037 during twlfeth Five Year Plan, renewable energy based power installations of 30 GW capacity are expected to come up. India has set for itself a very modest target of solar power generation at 20,000 MW by 2030. The country has also the potential to increase grid connected solar power generation capacity to over 200,000 MW. India can avail international collaboration in tapping the full potential of Rajasthan desert sun to achieve this ambitious target.

3.3.5 Wind Energy

India has been experiencing record years of new wind energy installations. Interestingly more than 95% of Indian Wind energy developments had taken place in 5 states (Tamil Nadu, AP, Gujarat, Karnataka and Maharashtra). Rajasthan is an emerging state with high potential. There are good prospects for extending the wind energy installations to other states. The Twelfth Plan envisions installing 15-17 GW of new capacity. The IEA has estimated total wind energy installations in India would be 66 GW by 2030 to produce 174 TWh per annum of power by 2030 and save 105 million tons of CO_2. By 2015, this industry will see investments of the order of USD 6 billion / annum and by 2030, it will be USD 9 billion / annum. It will create jobs for 1.25 lakh persons by that time. Some other international bodies have predicted that India could almost achieve 89 GW of wind power by 2020.

3.3.6 Hydroelectricity

Small hydropower projects of up to 25 MW capacity are the best options for Indian states like Himachal Pradesh and Uttarakhand, and also for the Northeastern states. It is possible to enhance the installed capacity from the present level of 3,200 MW to 15,000 MW by 2037. Since it is largely private investment driven, the future projects have to be carefully planned after a thorough environment impact studies and following coastal zone environmental regulations.

3.3.7 Biomass Gasification

It is predominantly to be developed as off-grid green power to rural and semi-urban areas. It can play a key role in the future for electrification of rural and remote communities. It can also replace the costly power generation sets based on furnace oil or diesel. There are good prospects to develop around 30,000 MW of power from biomass by 2037. The current challenges pertaining to urban waste utilization for power generation have to be overcome through their organised collection, establishment of a network of garbage based power stations around urban centres and getting over the teething problems to facilitate their profitable operation.

3.4 INAE VISION FOR ENGINEERING OF INDIAN ENERGY SYSTEMS

The INAE proposes to develop a shared vision with stakeholders for evolving engineering solutions that foster a cleaner and sustainable energy for India. Several ground challenges confront its engineering community in order to be at the forefront of developing globally competitive solutions to address energy engineering related issues in sectors like transportation, housing and industrial manufacture. The scientific knowledge and engineering skills have to be integrated and coordinated to evolve new energy sources, make existing energy generation and end use systems cleaner and improve the adaptability of emerging technologies. Developing sustainable energy systems do mean engineering of large and small systems with equally attractive efficiencies, restructuring energy engineering education for generating young engineers with competitive edge of knowledge, sensitizing engineering community in various disciplines on the collaborative advantage, initiating measures to protect intellectual property with high innovation content and to maximize the application potential of diverse energy systems. Emerging technologies in computer aided design and manufacture, novel materials, intelligent robotics, nano technology, bio and chemical technologies, system integration need to be developed with conventional engineering sciences to design more innovative products and systems rather than isolated components. INAE will strive to act as a facilitator for young engineers to take up challenging problems in Indian energy sector and to build their careers as individual inventors, competent entrepreneurs and highly skilled employees of Indian corporate bodies in energy sector.

INAE has taken several initiatives in the past to promote the cause of Indian energy sector. A brainstorming conference was held in Delhi in 2005 to facilitate stakeholders in the energy sector to deliberate on the synergy based approach for its growth. A national conference on hydrogen energy was held in the subsequent year to prepare a roadmap for introduction of hydrogen economy in India. A specialist Forum on Energy was established in 2007 by INAE to provide an interaction platform on energy related matters. The Academy has been actively participating in the activities of CAETS Working Group on low carbon energy technologies. In June 2013, INAE was chosen by CAETS to host the chair of its standing energy committee constituted in 2012. This is a major international responsibility being undertaken by the INAE in energy sector. The INAE also hosted Indo-Canadian joint initiative on clean coal technologies in December 2012.

3.4.1 Engineering Challenges in Achieving 2037 Targets

The role of advanced engineering and innovative technologies will increase significantly in coming years for harnessing renewable energy in India and to make the transition to low carbon energy economy more sustainable. This can create millions of jobs in Indian renewable energy sector by 2037 and an economic stimulus of around USD 1 trillion. For example, solar energy can shift about 90% of daily transportation needs from petroleum to electricity by increased use of hybrid automobiles. The focus areas for future engineering knowledge generation in India are large scale centralized and distributed renewable energy (solar, wind, hydro, biomass and geothermal) networks, and major and microgrid power transmission systems which are resilient to power blackouts, development of ultra large scale solar farms in sunny areas, development of solar powered electric vehicles and their charging stations around the country and large scale solar power manufacturing facilities. Indian engineers have to play a major role in adopting the advanced fuel cell technologies based on renewable resources for generating heat and electricity. Indian engineering profession has also to facilitate cleaner production of energy from coal, oil and natural gas during transition period.

The energy systems for transport and buildings in India offers immense challenges to the Indian engineering community in making them energy efficient. The Indian buildings accounts for nearly 29% of electricity consumption. By 2037, an estimated 1900 million m^2 will be the constructed building space in India as against 660 million m^2 built in space currently. It requires reengineering of building envelope, lighting, airconditioning, water heating and plumbing. One of the challenges is to increase the efficiency from 1 KW/ton of refrigeration to 0.5 KW/ton.

The Indian Transportation sector consumes around 27% of the total crude oil and its products. This is likely to go up to more than 45% in 2037. At present 98.5% of energy for this sector is met by conventional fossil fuel resources. The population of vehicles on Indian roads will be more than 300 million by 2037. India even with its per capita GDP in 2006 at USD 3310 has been experiencing a steep increase in vehicle ownership rate. The engineering challenges in energy reduction and introduction of renewable energy options in this sector will centre on fuel cell technology developments, use of hybrid transport vehicles and providing necessary supporting infrastructure. Priority has therefore, to be given to make road and rail transport systems in India more energy efficient and less dependent on fossil fuels.

3.4.2 Perceived Indian Strengths

3.4.2.1 *Indian Ingenuity*

Since its independence in 1947, India has demonstrated remarkable resilience and ingenuity in achieving economic and social successes. The green revolution, harnessing hydroelectric and nuclear energy, globalization of information technology are typical examples of Indian successes in agrisciences and engineering amidst tremendous regional and global competition]. For a country that was highly protectionist and regulated, the Indian industry has shown its remarkable fighting qualities in competing very effectively in various industrial sectors with global majors. The Indian takeover of overseas companies in steel, pharmaceutical and other sectors has demonstrated the Indian supremacy in corporate management. The outstanding progress made by India in nuclear field under international isolation and technology denial regime shows its national commitment to achieve a global position of engineering strength in spite of heavy odds. These achievements should provide lot of comfort to India as a nation to achieve smooth transition to low carbon energy systems by 2037 and beyond.

3.4.2.2 *Demographic Dividend*

India's current birth rate viz., 2.8% is likely to reach less than 1.7% by 2037. This evolution minimizes direct effects on demand on available resources and also quality of consumptions. India's window of opportunity under this head will be spread over a long time since its population control measures are slow compared to China and other countries. Accordingly, India will not experience any big crises over population aging till 2050. The country will continue to remain young in 2037. It has been predicted that India will take a demographic advantage over China in 2037 by 10%. The demographic potential will benefit India in real terms of its economic growth if it is accompanied by job creation and development of engineering skills.

3.4.2.3 *Primary Energy Intensity*

Decreasing energy consumption per unit of a given activity is one of the major objectives of the Indian energy planners. Energy intensity is a measure of the energy efficiency of a nation's economy and is calculated as units of energy per unit of GDP. A comparative information on the likely changes in the Indian primary energy intensity is given in Table 1. It shows that Indian household and transport energy sectors will show marked decline in energy intensity as compared to that in the primary commercial energy sector. This is due to increased efficiency of energy use, shift to better forms of energy and change in life style of the people. The steady increase in the need of primary commercial energy in the Indian economy is largely due to its increased demand, low indigenous production and high import costs. There is a strong need to bring down this component of energy intensity by 2037 through substitution of non-renewable with renewable energy with a strong indigenous base.

	Energy Sector	**1950**	**1970**	**1990**	**2010$^+$**	**2030**
1	Household	46	33	19	7	5
2	Commercial	18	23	28	32$^+$	35$^+$

3.4.3 Perceived Areas of Concerns

3.4.3.1 *Environmental Footprint*

The scale of projected growth of energy demand up to 2037 raises the environmental concerns of increased CO_2 emissions which require adoption of CO_2 capture technologies (pre and post combustion options) and subsequent gradual substitution with low carbon intensity technologies. Since India will be relying fairly heavily on coal even in 2037, adverse environmental footprint will be a matter of concern if proper corrective actions are not taken.

3.4.3.2 *Switchover to Market Based Growth Models*

The main challenge for the public sector dominant coal, oil and gas based energy sectors is to totally switchover to a market based model in which Indian energy companies have to compete on a level playing field with their global and national competitors and sell the energy at globally determined market prices. The dismantling of controlled price structure is a major challenge for India.

3.4.3.3 *Long Term Renewable Energy Prospects*

While the short term prospects for the expansion and growth of renewable energy sector remains quite strong due to government subsidies, their long term prospects may look less attractive if the subsidies are either partially or totally withdrawn. A strong public – private understanding on their long term growth becomes a vital factor for renewable energy sector.

3.4.3.4 *Infrastructure Weaknesses*

India still suffers from major infrastructure bottlenecks in terms of housing, power transmission systems, telecommunication links, rail and road transportation, townships etc. These require long terms investments. They are vital for the future growth of Indian energy sector. The poor quality primary and secondary education systems hamper blue coloured job creation in rural and semi urban areas.

3.4.3.5 *Good Governance*

A good system of governance endowed with transparent administration with minimum red tapism, efficient implementation of major projects, and effective legal system with minimum time duration are vital for rapid future growth of Indian energy sector.

3.5 CONCLUSION

The Indian energy scenario presents a complex picture with several roadblocks for rapid growth in the coming years. The academic community, the industry and the government have to share the burden of taking the country forward in this difficult sector. The future transformation can come about through endogenous engineering knowledge growth linked to innovation and willing to learn from past mistakes. INAE stands hand in hand with the nation in achieving the desired growth parameters in the energy sector.

SS4 : HEALTHCARE

4.1 PREAMBLE

The Indian healthcare industry, which comprises hospitals, medical infrastructure, medical devices, clinical trials, outsourcing, telemedicine, health insurance and medical equipment, is expected to reach US$ 160 billion by 2017.

On the back of continuously rising demand, the hospital services industry is expected to be worth US$ 81.2 billion by 2015. The Indian hospital services sector generated revenue of over US$ 45 billion in 2012. This revenue is expected to increase at a compound annual growth rate (CAGR) of 20 per cent during 2012-2017, according to a RNCOS report titled, 'Indian Medical Device Market Outlook to 2017'.

Further, the healthcare industry in India is experiencing gradual transition from paper files to electronic mediums. The Indian healthcare assisted by IT market has been growing tremendously over the past few years. It is expected to grow at a CAGR of around 22.7 per cent during the period 2013-2015.

The hospital and diagnostics centre in India received foreign direct investment (FDI) worth US$ 1,914.28 million, while drugs & pharmaceutical and medical & surgical appliances industry registered FDI worth US$ 11,318.32 million and US$ 653.45 million, respectively during April 2000 to June 2013, according to data provided by Department of Industrial Policy and Promotion (DIPP).

More so, the other related segments such as genetic testing market is expected to grow at a CAGR of around 9 per cent during 2012-2017 and that of the diagnostic services market in India at a CAGR of around 26 per cent during 2012-2015. All the growth is based on the foundation on huge investments, fast expansion into tier II & III cities, and strong government support to strengthen the healthcare infrastructure in the country.

The Indian healthcare providers plan to spend Rs 5,700 crore (US$ 897.64 million) on IT products and services in 2013, a seven per cent rise over 2012 revenues of Rs 5,300 crore (US$ 834.65 million), as per a report by Gartner.

Several key trends are giving impetus to the growth of India's healthcare sector. Of these, medical city is relatively a new concept that offers immense growth opportunities, in addition to the medical tourism. India is also regarded as the most competitive destination with advantages of lower cost and sophisticated treatments. Due to such promising factors, the medical tourism has great potential in India.

The industry in India is pegged at US$ 1 billion per annum, growing at around 18 per cent and is expected to touch US$ 2 billion by 2015. India has witnessed an influx of patients from Africa, CIS countries, Gulf and SAARC nations, Pakistan, Bangladesh and Myanmar, who mainly come for organ transplant, orthopedic, cardiac and oncology related problems.

The hospital industry in India, at least in the Tier I cities, is cost-effective and has top notch talent pool comprised of highly qualified Doctors and Nurses. It is therefore not surprising that the sector is growing exponentially and is likely to see huge growth in the coming decades. What we see today is only the tip of the iceberg!

4.1.1 Government Initiatives

The Government of India has decided to increase health expenditure to 2.5 per cent of Gross Domestic Product (GDP) by the end of the Twelfth Five Year Plan (2012-17). 100 per cent FDI is permitted for health and medical services under the automatic route.

In a recent initiative, 348 essential medicines will now come under price control in India. These currently contribute Rs 13,033 crore (US$ 2.05 billion) to the total annual sales of Rs 72,762 crore (US$ 11.46 billion), according to market research firm IMS Health's analysis.

Key developments in the healthcare sector are as follows:

- Health for all remains one of the priority sectors for the Government
- The Ministry of Health & Family Welfare has been allocated Rs 37,330 crore (US$ 5.87 billion). Of this, the new National Health Mission that combines the rural mission and the proposed urban mission will get Rs 21,239 crore (US$ 3.35 billion), an increase of 24.3 per cent over the Revised Estimates (RE)
- Rs 4,727 crore (US$ 744.41 million) for medical education, training and research

4.1.2 What is the Road Ahead?

The country's healthcare system is developing rapidly and it continues to expand its coverage, services and spending in both the public as well as private sectors. This is creating a large market for hospital information systems and other healthcare-related IT solutions.

The favourable demographic virtues offer an attractive market for healthcare providers and investors in India. An increase in foreign investment inflows and private equity (PE) deals in the industry's various segments have also been noted, in addition to the increased focus received from the Government.

4.2 CURRENT INDIAN HEALTHCARE SCENARIO

There are several dimensions related to the Indian Healthcare sector. These range from efforts by the Government of India and the Private sector to business, academic and user perspectives, capacities and capabilities and investment scenarios.

Healthcare sector in India presents unique opportunities and challenges. It has been growing rapidly over the last couple of years and is expected to double its size to US$ 100 billion by 2015 from its present level of US$ 60 billion.

Among several challenges, shortage of skilled manpower has been identified as one of the most critical constraints that the sector is confronting with. According to the High Level Group Report on Universal Health Coverage, a substantial scale-up of the healthcare workforce is needed across cadre. There is a need to increase doctor to population ratio from 0.5 to 1 per 1000 population and nurses from 0.9 million to 2.7 million by 2020. The report further accentuated that skilled support services should be provided by suitably trained nurses and allied health professionals.

While there is a huge need and demand for skilled workforce, there are neither national occupational standards nor any mechanism to streamline and standardize education / skill development for Allied Healthcare and Paramedic Profession in the country. As a result, there is an inconsistency in the competency level, affecting efficiency, productivity and delivery of services.

The Healthcare Sector Skill Council is a unique initiative of the Confederation of Indian Industry (CII), with financial support from National Skills Development Corporation (NSDC), to bridge this gap and play a proactive role in creating a vibrant eco-system for quality education and skill development in allied healthcare space in the country.

The Healthcare Sector Skill Council (HSSC) is a Not-for-Profit Organization, registered under the Societies Registration Act, 1860. The Council has been promoted by Confederation of Indian Industry (CII) and leading Healthcare Industry Members representing both public and private sector, financially supported by NSDC. The key objective of the Council is to create a robust and vibrant eco-system for quality education and skill development in paramedics and allied healthcare space in the country. In addition, the Healthcare Sector Skill Council serves as a single source of information on healthcare sector with specific reference to Skill and Human Resource Development in India.

The Council is aimed to develop National Occupational Standards & Qualification Packs for various job-roles in paramedics and allied healthcare, Identify skill-gaps, Design Courses and Training Content, Set Standards, Put-in place an Assessment & Certification Mechanism, Accredit Training Institutes, Provide Placement Support and Help Institutes Build & Upgrade their Capacity through train-the-trainer programme.

4.3 INDIAN HEALTHCARE SCENARIO IN 2037

4.3.1 Future Trends in Healthcare Industry in India

According to recent studies conducted, the customer's (patient) aspirations are fast changing. Customers are growing more aware of their health needs, demand quick response, and quality care less waiting times, and above all - demand nearness of the healthcare unit to them.

Customers now demand better quality care; they however now do not want to travel much as in earlier days.

Though the billing and pricing are important, they are not a very high priority now as insurance reach is getting stronger (to the tune of 40 per cent among patients visiting an urban hospital). If this is the window to the future of healthcare, then it leaves immense opportunity for existing hospitals across the country to revamp and re-organize in order to woo back their immediate local drainage population as the competition would heat up soon. The patients would have a lot to choose from, now being insured. Public spending is likely to increase beyond 20%, there is room for everyone in the organized private healthcare sector.

The entities who have noted this advantage to name among the other few are Apollo and Fortis with its cumulative market cap of around $ 5 billion and this may be considered as a reflection of the healthcare scenario of the present and future of Indian healthcare. Another shining example in India is the Medanta Medicity hospital in Gurgaon, Haryana. The hospital boasts of top-notch Doctors who are perhaps one of the best in the country.

India presently has a bed deficit of approximately 30 lakh beds as per the WHO recommendation of four beds per 1000 population. Considering even a 250 bed hospital on an average, the country would need 12,000 hospitals in the near future. As almost 80 per cent of this would be fulfilled by the private players, a huge rise in IPO's and premium commanding players in the arena would flutter bringing in interesting times for the healthcare industry.

4.3.2 Opportunities

4.3.2.1 *Emergence of Wearable Devices Industry*

Let us first take a look at the United States. The wearable devices industry, which includes smart watches and glasses, will be worth $19 billion by 2018. That is a big jump over the $1.4 billion the industry is expected to pull in this year, according to Juniper Research.

Why such massive growth? Juniper points to two factors: Consumer demand and the rise of subscription services. The latter is particularly the key. While most wearables are being sold solely as devices right now, it won't be long until every wearable maker also offers a separate service component to generate recurring revenue. Consider devices like the Filip, a kid-friendly smartwatch that can also make phone calls. By teaming up with AT&T, Filip is creating an extra revenue stream that goes beyond just device sales.

If Juniper is right, devices like the Fitbit Force are going to be big moneymakers. In other words, hardware + demand + services = $19 billion. Juniper's Research comes not long after fellow research company Berg Insight estimated that wearable device sales will climb to $64 million by 2017.

“A perfect storm of innovation within low power wireless connectivity, sensor technology, big data, cloud services, voice user interfaces and mobile computing power is coming together and paves the way for connected wearable technology,” writes Berg analyst Johan Svanberg. He, however, takes Berg Insight's observations further, and argues that, in order for the wearable industry to see those big numbers, companies first have to create multi-purpose devices that can also stand on their own.

Several companies are mushrooming in the wearable device space, and one such example is Fitbit. There are quite a few players now in the fitness tracker space. Fitbit has introduced the Fitbit Force, a bracelet that combines the company's expertise in digital fitness tracking with some basic smartwatch functionality (see figure).

The bracelet has a new small screen right on the band so one can easily tell the time and how many steps one has taken or how many miles we've gone. The device tracks the steps we've taken, the distance we've gone, the calories we've burned, the floors or stairs we've climbed, and even how long we have slept.

It can show most of that information on the screen or we can view it through the relevant application, which pairs with the tracker via Bluetooth 4.0.

It is interesting to see how Fitbit is tapping into the Bluetooth capability even more, sending information from the phone to our wrist. When paired with an iPhone running iOS 7, we see incoming call notifications right on the display. While that feature isn't available yet for Android phones, Android phones have their own trick. With any NFC-equipped Android phone, we can tap the Force to the phone and it will automatically launch the Fitbit app.

The Force joins a crowded market of other fitness devices and new smart watches, including Fitbit's family of devices. Fitbit says "one size doesn't fit all," and many other companies including Nike, Jawbone and now Samsung would likely agree.

We expect to see a proliferation of fitbit type of devices in India and elsewhere in the coming years and decades. This, in turn, is likely to spawn major innovation and developments in the IT & software space.

4.3.2.2 *Exponential Growth of Start-Ups in the Area*

The booming healthcare sector is seeing a huge traction in the startup space abroad and also in India. E-healthcare firms are capitalizing on this growth by launching various Android and iPhone applications. In fact, eHealth has picked up a lot of momentum since VCs are not too excited about the eCommerce space.

A few success stories in this space are Healthcaremagic.com, HealthKartPlus.com (online pharmacy and drug database) etc. Over the next one or two decades, we expect to see a surge in start-ups in the healthcare sector in India.

Another example of a successful effort in the healthcare space is Neurosynaptic Communications, a Bangalore based company with a mission to develop ICT based products and technologies. Neurosynaptic believes that technology can enable access to essential resources at affordable prices to the masses and is engaged in the development of low-cost indigenous technology for application in rural areas. Neurosynaptic has decided to focus primarily on two problems of Healthcare Delivery and Agriculture.

At this point in time, the healthcare regulatory regime in India is weak, unlike what we see in the United States. We expect that with increasing awareness in this sector, the regulatory issues would be crystallized with each passing year.

4.3.2.3 *Population*

Many would consider that the massive population of India would be a bane. But it has turned out to be an immense business opportunity across industries like telecom, broadcast and healthcare.

The 1.17 billion population of 2009 is projected to reach 1.33 billion in the next 10 years. Of which almost 60 per cent of population is in the 15-64 year age group - which is the active earning population and will primarily drive the industry, especially the healthcare insurance industry which will make healthcare accessible over a period of time to majority of the population.

The disposable income of Indian families has increased by a whopping 70 per cent since 2004 and is growing at a pace of 10 per cent ever year. This will lead to increased demand for good quality healthcare even at a premium.

4.3.2.4 *Insurance*

It is estimated that the penetration of health insurance in India is only 2 per cent of the population. However, this figure is expected to rise to a penetration of almost 20 per cent in the next five years keeping in mind the high growth seen in disposable income of the Indian families. Though this figure is the country's average, the percentage of insured visiting urban private setups even now is in the range of 20- 60 % of the hospital admissions. With better government health schemes for the poor, for example, Aryogyshree, National Rural Health Mission and the kinds, the health upkeep of the poor is also not far behind.

4.3.2.5 *Comparative low costs and Medical Tourism*

As per industry studies, almost five million foreigners had availed treatment in Indian healthcare setups by 2008. With surgical cost almost ten-fold in western worlds, the estimated 15 billion dollar medical tourism industry will only grow further. This has led to the creation of health cities and medical tourism hub. Now with immense support of the Indian tourism ministry and its dedicated medical arm, the medical tourism industry in India will grow in leaps and bounds.

4.3.2.6 *Budgetary incentives and PPP*

With various tax incentives given by the government for the healthcare sector and various states realizing the fact that PPP is the best way to bring in quality healthcare at no further costs to them, a huge spurt of activity is seen in terms of new hospital projects launched and PPP initiatives concluded across the country.

4.4 THE FUTURE

Breaking the conventional model of business, the coming years will see a great out-of-the-box thinking by strategists in the field of healthcare, beginning with the way healthcare is delivered.

To begin with, a rise in retail clinics, single speciality, secondary and tertiary care centres are seen coming to the fore including the recent examples of NOVA day care, BEAMS & Apollo clinics. Operations and management contracts are being handed over to outsourced partners.

The recent trends also show how the hospitals have become quality conscious. Reputed hospitals across the country have hired a reputed healthcare consultancy firm to do a quality gap analysis and help them streamline operations and management and suggest ways to bring about better sustainability.

The tier 2 & 3 cities have suddenly become attractive to the healthcare players, especially because of the tax sops and increasing disposable incomes among Indian families across the country and dearth of quality healthcare infrastructure in these locations.

Specially focused on medical tourism, health cities are audaciously being designed and executed and hospitals with bed strengths of 1500/2000 which were never heard in the private domain are now coming to light.

Once unheard of, now the non-core operational aspects including laundry, kitchen, housekeeping, security, all are being outsourced, and the primary focus is put on the hard core patient care. Even revenue centric departments such as imaging, laboratory and pharmacy are being outsourced. Telemedicine and remote diagnosis is seen as a rising trend, as part of the outsourcing model.

The earlier model of hundreds of visiting doctors being empanelled by the hospital is also slowly fading away and the full time practice is taking a preference in choice of clinical operations. Moreover, with patient awareness increasing, the patients are not hesitating to take 'second opinion'. Specialized second opinion centre have opened and more could be seen in near future. Franchising models followed by both the public and private, by partnering with NGOs and individual doctors to provide affordable and quality healthcare on pay per service model and other incentives has proved to be mutually beneficial to all stakeholders.

In the private sector, leading healthcare entities have been extending their brand name on a royalty/franchise basis to interested partners to leverage on the brand and attract patients. This is mutually beneficial to both the provider (he gets more patients because of brand) and the brand provider (they earn royalty without any capital inflow)

4.4.1 Health Insurance

Industry gurus have always been suggesting the best governance when the government does not deliver a product or service, but monitors its quality and ensures that the people get the relevant service or product through able private players. In this case, government policies are seen to be changing and their role in healthcare is seen shifting from healthcare delivery to financing the delivery of care. With their launch of health insurance schemes like Rashtriya Swasthya Bima Yojna, Aroygashree and other similar schemes has tremendously improved healthcare delivery through private players, the schemes will cover millions of BPL patients in the years to come. The government will save billions on the capital costs and HR costs by having the private player invest in the same.

With opening of health insurance to private players, the insurance sector is booming. Especially with rising disposable incomes, and the highest population being in the earning age group of 15-64 years (60 per cent of population), the insurance reach is bound to grow from the present meager two per cent to 20 per cent as estimated by the industry experts. This will bring in demand for better quality care and a dominant role of insurer on choice of healthcare units for patients in reference to quality and professionalism. Patients will have a lot to shop around before choosing the 'right care provider' as he will be armed with the vital medical insurance.

The need for keeping their insured clients healthy, has spurted a trend in providing free health checkups in the policy package so that the clients are detected early for early intervention for various diseases, especially the life style diseases, and thus save on immense cost burdens to the insurer in the future in terms of costs towards treatment of their patrons. This will also lead to a rise in opening of specialized executive health checkup centres as stand alone or in the hospitals in the times to come.

4.4.2 Human Resources and Medical Education

IDFC security studies reveal that there is a clear bias within skilled professionals including doctors towards the private sector. About 72 per cent doctors are based in Tier-I cities (mainly because of lack of incentives, lack of focus on quality standards and inadequate infrastructure in the public health sector).

Even then, the private sector finds difficulty in bridging the deficit of manpower. As stated above, there is a shortage of 1.5 million skilled professionals including doctors and nurses and administrators. The reason for the same is mainly due to lack of adequate medical education centres in required numbers. Governments have liberalized the utilization of AYUSH practitioners through a GR into mainstream medical care provision, especially in tier 2/3 cities, to bridge the gaps, however the much awaited entry of private players in medical education will bridge the gap further. With recent opening of numerous hospital management colleges, the gap to provide able administrators would surely be bridged and more such institutes will be seen flourishing in the times to come.

PPP activities have been seeing the light of the day in states like Uttar Pradesh inviting proposals from private partners to help them setup and run medical and para-medical colleges to streamline operations, to bring in a professional insight and outlook and further attract the vital professionals to impart medical education.

4.4.3 Funding and Private Equity Infusion

With the country's healthcare industry poised to grow to 125 billion USD in the next five years, and only two or three major listed companies with a market cap of less than $ five billion existing, there is huge potential for many other players to come into the fray.

With new conventional model of healthcare delivery and for the first time EBITAS in healthcare reaching the figures of 25 per cent and above in such businesses, venture capitalists and private equity is hunting for the right partners every day. The growing demand has also attracted a lot of foreign players to venture into the healthcare industry and are collaborating with the existing Indian players in creating a chain of healthcare units not just in India, but in foreign locations too.

Business related to medical equipment, and devices is also growing at a rapid pace, and with more number of hospitals in the fray, this industry and the pharma industry will grow further due to rising healthcare demand.

4.5 CHALLENGES

4.5.1 High Capital Costs

Depending on the region and real estate costs, an average hospital requires capital infusion of Rs 40 lakhs to a crore per bed (& even more). Industry estimates suggest that any hospital with capital costs of more than 50 lakhs per bed has high gestation period and even may be unviable. Land and building together account for almost 40 per cent of the total project cost and affects the viability depending on the resulting per bed cost.

4.5.2 Medical Equipment

Contributing to almost 40 per cent costs in a tertiary setup, the medical equipment though cutting edge at the time of purchase poses the threat of inevitable obsolescence within five to seven years of setup. This problem is compounded by the fact the most of such equipment is imported and very few local reputed manufacturers exist. This will lead to apportioning to higher treatment costs and will further lead to lesser competitive edges and low utilisation rates resulting in an undesired operating margins.

4.5.3 Human Resources

As Dr Prathap Reddy puts it, "the biggest challenge for him and Apollo is filling the void of human resources". The fast-expanding domestic healthcare industry is the third largest employer, but is severely short of manpower, according to him.

As per Ministry of Health, there is a shortage of approximately half a million doctors, a million nurses and the deficit needs to be filled in the next five years. Such shortage will lead to exponential salary hike demands, and further lead to high patient care costs.

With organised sector being the preferred choice now, there will be a huge demand even for the skilled and quailed health administrators to run the show. Considering one skilled and quailed administrator is required for every 50 employees, there would be a requirement of almost 50000 such healthcare professionals in the near future.

Highly regulated environment and unrealistic stringent norms and restriction of entry to the private entities in the field of medical education has led to further deficiencies in terms of number of skilled professionals being released for intake by various hospitals.

4.5.4 Conventional Models of Business

Rarely an out-of-the-box idea of running a healthcare business is seen. Recent niche segments of single speciality centres have been very few. Even in the public health sector, millions of square feet of space is left under utilised, expensive equipment ill-maintained and lack of skilled professionals adding to the woe, still do not find adequate initiatives happening towards outsourcing or even PPP.

Almost 90 per cent of private sector in India is run under the unorganized sector. The clinical establishment bill also has faced immense opposition and a professional healthcare consultancy firm guided healthcare business is not still seen frequently.

The conventional model would need to be broken to mitigate the presently seen long gestation periods of five to 10 years of which almost three years are spent in project conceptualization to commissioning.

The conventional model of healthcare business would need to change to bring in untapped opportunities, operational efficiencies and better profitability. This would also attract better private equity which is now diverted to more lucrative industries.

In the public healthcare sector the infrastructure is provided based on the size of the population instead of epidemiological profile. This many time results in under-utilization of infrastructure, and ultimately not meeting the demands of the local population and drainage.

4.6 INAE VISION FOR ENGINEERING OF INDIAN HEALTHCARE SYSTEMS

The INAE recognizes the following engineering challenges, perceived strengths and areas of concerns in achieving a sustainable future for India in the healthcare sector.

4.6.1 Engineering Challenges in Achieving 2037 Targets

4.6.1.1 *Emergence of wearable devices and body area networks*

With rapid innovations in computing, networking and miniaturization, we will see a plethora of wearable devices in the healthcare sector. This is likely to be a game changer in the Indian context.

With the Indian population ageing rapidly, wearable devices will be critical for old age groups, those that need round the clock nursing and care. People with disabilities will find that doctors would be available on demand, thanks to the technical advancements the times.

Consumer demand will help drive wearable sales of billions of dollars by 2037.

4.6.1.2 *Doctors on Demand*

By 2037, more and more Doctors will go online and medical advice will be available online to a large fraction of the Indian population. This will happen since by 2037, Internet is likely to penetrate every corner of the country. Success stories in this space such as Healthcaremagic.com, HealthKartPlus.com (online pharmacy and drug database) will be game changers.

4.6.1.3 *Proliferation of Start-ups*

Over the next one or two decades, we expect to see a surge in start-ups in the healthcare sector in India. There will be a convergence of the technology, software and healthcare space. We foresee a convergence between the medical profession and the engineering profession and this will likely change our mindset.

4.6.2 Perceived Indian Strengths

4.6.2.1 *Trained Manpower*

India has a large trained manpower and will continue to churn out experts in the healthcare sector. With convergence across diverse areas (e.g., healthcare and engineering), we expect to see a well rounded talent pool with both depth and breadth in the healthcare sector.

4.6.2.2 *Emergence of New Areas/Disciplines*

We expect to see the emergence of new areas/programs in the healthcare sector, for example, healthcare analytics, big data in healthcare, healthcare IT and healthcare solutions.

(i) Convergence of Engineering and Medicine

All signs point out that by 2037, a quality Doctor would need to know basics of healthcare engineering and a quality Engineer in IT/Computer Science/Communications would need to know basic medicine and healthcare. The convergence will happen at a rapid rate. We are already seeing a trend where start-ups in healthcare leverage IT and software in a big way.

(ii) Cost-effective healthcare across the country

Indian healthcare is extremely cost-effective in the region. This is evident from the growing number of patients, both from India and abroad, flocking to the top hospitals in the country, e.g., Medanta Medicity, Fortis, Apollo, NIMHANS, AIIMS, Tata Memorial, Lilavati, Shankara Nethralaya, to name a few.

4.6.3 Areas of Concern

4.6.3.1 *Lack of Innovation & focus on IP*

If India needs to make a global mark in the healthcare sector and be competitive in the space, it needs to seriously focus on Innovation and Intellectual Property (IP). This will only be possible when both

Government and Private players emphasize the importance of Innovation and IP and provide incentives to experts in the area.

4.6.3.2 *Lack of quality hospitals & clinics across the country*

Most of the large and quality hospitals in India are located in Tier I cities. Tier II and Tier III towns have woefully inadequate healthcare facilities including quality hospitals and clinics. The situation is much worse in villages where there are hardly any doctors. There needs to be a country wide network of hospitals, clinics, research centres so that the best advice is available to a patient in the remotest corner of the country. This is where we truly need to bridge the digital divide.

4.6.3.3 *Need for Global Collaboration*

In a highly competitive space such as healthcare, India needs to collaborate with experts and high quality institutions across the globe. This is one way for India to create IP and prototypes in the area.

4.6.3.4 *Highly Skilled Manpower*

India would need a large number of highly skilled manpower in the healthcare sector – ranging from nurses on the one end, to researchers and specialized doctors, at the other end of the spectrum. This will only happen when our focus shifts from 'quantity' to 'quality'.

4.7 CONCLUSION

With the personal disposable income rising by more than 70 per cent and the over all income of the population rising, the demand for better quality in healthcare is bound to increase exponentially. For International healthcare quality, this is just the beginning. With only 20 per cent of healthcare delivery being provided through public health units and the government not intending to spend more on capital expenditure, more PPP projects and private healthcare initiatives would see the light of the day.

To bridge the immense HR gap, especially in the clinical and professional sectors the government is mooting the idea of corporatizing medical education and it is just a matter of time that private run non-trust based medical education on commercial lines will be seen across the country.

Health insurance sector has never seen better days than today. With the population seen as a strength, even the present two per cent to five per cent penetration would mean millions and billions in business. The projected penetration in the next five to 10 years is 20 per cent of the population, because the earning population of 15 to 64 year age group comprises more than 60 per cent of the total population who can afford health insurance. With rising awareness and the acknowledgement that insurance is the way to a healthy life, the demand for medical insurance will only rise further. Trend reveals that at least in the large corporations and private organizations including public sector units, insurance is provided as a norm to all employees. This trend will only increase in time to come.

With the increase in population and to bridge the gap of the number of beds, hundreds of quality healthcare units will come up. A lot of earlier untapped models will be tapped and the consumers will have plenty to choose from in the coming years and decades.

With tax sops and other government incentives, more secondary and tertiary care units will open in Tier-2 /3 cities. Further, medical tourism will see a marked boom in the years to come. Health cities with an aim to woo medical tourist is on the rise, and the healthcare players will leverage on the integrated medicine model by providing Ayurveda, Homeopathy, Unani, Yoga and others along with the modern medicine. This holistic approach will attract patients from far off lands, because the cost of care is almost one tenths of the western world costs. This change is already happening in India.

Technology will play a major role in bringing quality in healthcare, be it better nursing, communication systems, patient monitoring devices or telemedicine to provide low cost diagnosis to remote patients. Companies such as HCL, HP and Microsoft are already investing heavily in healthcare technology and Google is trying to ambitiously woo the consumers for a centralized healthcare database. Thus what is in store for the future of healthcare is limitless.

Information Technology, Software, Communications and Cloud Computing will play a major role in ensuring that healthcare is not confined to Tier-1 cities in India, and in fact, reaches the remotest corners of the country. New paradigms in healthcare will be in place by 2037. We will see proliferation of a plethora of wearable devices, body area networks, various categories of sensors – both intrusive and non-intrusive, and more sophisticated medical equipments and systems. Today's large medical equipments are likely to become miniaturized, thanks to great strides in IT, VLSI and Embedded Systems. The coming decades will see a plethora of new Healthcare Services and Applications. A clear picture of what the future in Healthcare will look like in 2037, is however anyone's guess.

SS5 : ENGINEERING EDUCATION

5.1 PREAMBLE

Indian higher education system has expanded at a fast pace by adding nearly 25,000 colleges and more than 8 million students in a decade from 2000-01 to 2010-11. As of 2011, India has 42 central universities, 275 state universities, 130 deemed universities, 90 private universities, 5 institutions established and functioning under the State Act, and 33 Institutes of National Importance. Other institutions include 35,000 colleges as Government Degree Colleges and Private Degree Colleges, including 1800 exclusive women's colleges, functioning under these universities and institutions as reported by the UGC in 2012. It has created social opportunities for people. It has fostered the vibrant democracy in our polity. It has provided a beginning for the creation of a knowledge society.

Expansion, inclusion, and rapid improvement in quality throughout the higher and technical education system by enhancing public spending, encouraging private initiatives, and initiating the long overdue major institutional and policy reforms should form the core of our efforts to address the continuing infirmities despite the growth.

Notwithstanding the impressive expansion, it is evident that the system is under stress to provide a sufficiently large pool of skilled human power that is equipped with the required knowledge and technical skills to cater to the demands of the economy. India is almost unique in having a demographic advantage with about 70% of the population below the age of 35 years. Actualizing this advantage comes through all encompassing reform in the technical education sector. INAE stands hand in hand with the national education authorities in this most crucial endeavor.

By 2050, India is projected to have 1 billion employable people. Our efforts must go towards channelizing this human resource into enhancing national intellectual property and productivity. Education must also be taken to include the skills that transform what is learnt towards things useful for society. It is in this expansion of the scope of engineering education, going beyond the hallowed halls of academia that INAE sees itself playing a crucial role. It is a natural via media between formal education and industrial training.

As per reports, 600 million people will join the global workforce between 2010 and 2030, and 60 per cent of these workers will be from China and India. This underlines the importance of China and India in providing the global labour market with skilled, employable workers—but is India a frontrunner in this race?

(Source: Eleventh Five Year Plan (2007–2012), Social Sector, Volume II, Planning Commission Govt of India, Oxford University Press & International Engineering Education Proc. INAE-CAETS-IITM Conf, Eds. Natrajan, Ananth & Singaperumal, World Scientific, 2007)

5.2 TRENDS IN HIGHER EDUCATION

The private sector has played an instrumental role in the growth of higher education, with private institutions now accounting for 64% of the total number of institutions and 59% of enrolment in the country, as compared to 43% and 33%, respectively, a decade ago. The Government has also given the required thrust to the sector in its Five Year Plans. During the Eleventh Plan period (2007–2012), India achieved a Gross Enrolment Ratio (GER) of 17.9%, up from 12.3% at the beginning of the Plan period. Thus the student enrollment in higher education has grown at a CAGR of approximately 10.8% in the past decade and institutions at a CAGR of 9%. Various legislative actions were also taken during this period, including the introduction of the Higher Education and Research Bill, the Educational Tribunal Bill and the Foreign Educational Institutions Bill, to enhance transparency and quality in the sector.

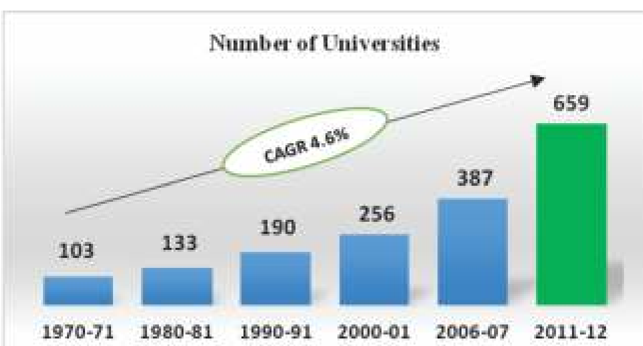
Government has planned expenditure of INR 1,107 billion on higher education during the Twelfth Five Year Plan, 30% more than the previous. Professional courses are growing significantly faster.

Lack of flexibility in changing paths or streams of expertise is the hallmark of education in India as compared to many countries of the west. The rigidity of the educational system plus the narrow focus of industries have led to lack of cross-fertilization of ideas and talents among and between the streams. INAE, being the repository of expertise from the widest variety of knowledge endeavors is uniquely placed to bring to a level of mixing and matching between the disciplines that cannot but be beneficial for the country. India lacks adequate infrastructure in higher education.

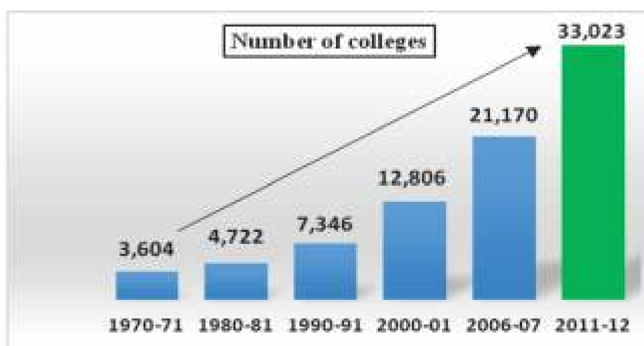
While public expenditure on education has increased, the percentage share of GDP spent on higher education came down from 0.77% in 1991 to ~ 0.7% in 2008. The Government increased the budget allocation for higher education to INR 850 billion in the XI Five-Year Plan and intended to expand educational facilities. Planning Commissions identified a resource gap of INR 2.2 trillion.

Students continuing on to higher degrees in science and engineering in India is small as compared to China. What this would mean for our innovative competitive edge is anyone's guess. Although Figures 1 and 2, show encouraging trends, yet do not promise as precursors to paradigm shifts in enrollment in Higher Educational Institutions, particularly in science and engineering.

The number of universities has grown more than Six times in the last four decades

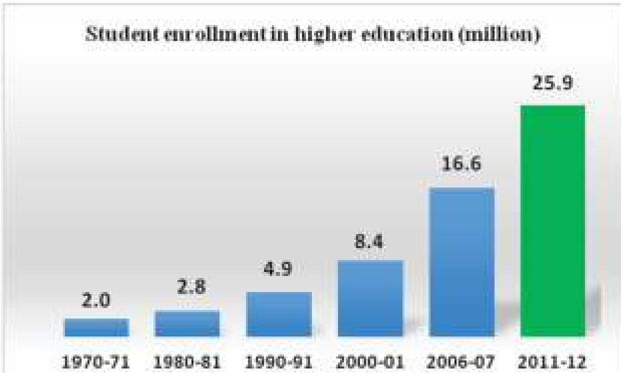


India has more than 33,000 colleges with one-Third of the college having been set up in the last five years

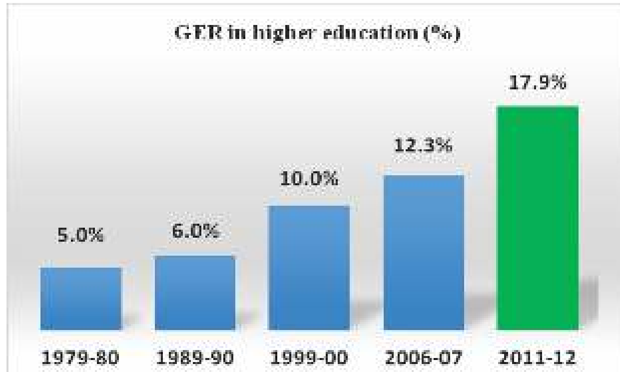


There were 12,748 diploma-granting institutions in the country as of 2011-12

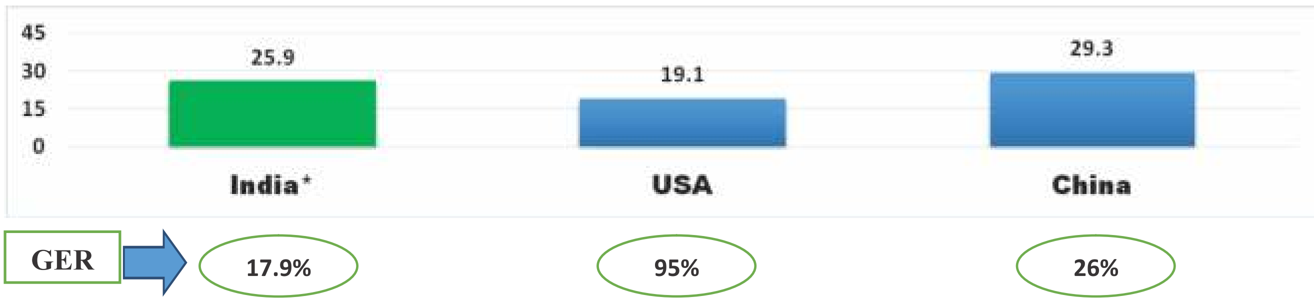
Student enrollment in HEIs has grown 12 times in the last Four decades



GER in higher education has reached close 18% in 2011-12



India ranks second in the world in terms of enrollment of students in higher education institutions



Comparison with other countries (2012 data for India; 2009 data for the US and China)*
Using global definition of GER (18-22 age cohorts), India's GER was 20.2% in 2011-12)

Source: Ministry of Education of People's Republic of China, Twelfth Five Year Plan: Chapter on higher education, UNESCO: Global Education Digest 2011. National Center for Education Statistics USA.

Fig. 1 : Some significant Data on Growth of Higher Education

Students	Academia / Research	Industry
▶ Access to accurate and updated information on	**Tiered industry structure**	▶ Greater corporate participation in the sector through initiatives such as setting up of the Council for Industry and Higher Education Collaboration (CIHEC)
▶ HEIs and courses on a centralized portal for parents and prospective students	▶ India's higher education sector will be relatively more consolidated with larger institutions, with new institutions coming up only for specific purposes	
▶ Fewer admission tests	▶ Multiple types of institutes, with distinct objectives and models, will co-exist in the system:	
▶ Increased student financial aid support from the Government	▶ Research-focused institutions such as innovation universities, excellence clusters and research networks	

- More international students

- Teaching institutions offering a wide range of programs, including innovative inter- disciplinary ones
- Vocational / Employment-focused institutions such as community colleges and polytechnics, with entry and exit options from mainstream higher education for students
- For-profit institutions in select areas that are higher education-deprived
- Open and distance learning will remain the most cost-effective way of reaching under-penetrated geographies and customer segments
- National knowledge clusters will be built on a collaborative model between academia, industry and research institutions

Increased international alignment

- Increased alignment with international education systems such as adoption of the credit / semester system and four-year courses at the undergraduate level
- Increased international linkages for research, faculty development, joint and dual degrees, etc.
- International accreditations will become more popular (such as AACSB's accreditation of ISB)

Enhanced autonomy

- Institutions will enjoy greater academic and operational autonomy

Government and regulators

- Greater coordination between ministries and agencies and fewer regulatory and procedural bottlenecks
- State Council for Higher education to coordinate and plan development of state HE systems
- Outcome-linked government funding
- Differential treatment of various categories of Institutions (research, teaching, etc.)

Source: Higher Education India: XII FYP (2012-2017) and beyond

Fig.2: Emerging Higher Education Scenario

5.3 TECHNICAL EDUCATION SYSTEM

In India, the role of the technical education system vis-à-vis its mandate is defined by a multitude of organizations and agencies.

The state of Indian vocational institutes is deplorable. For a population of 1 billion, India has a meagre 10,000 vocational training institutes (ITIs)—and most work with outdated technology and pedagogy. So, while the conventional education system does not help students develop employable skills, the lack of credibility and outdated nature of vocational and technical education make it an unpopular option among students. Additionally, the system's lack of flexibility means it is difficult for candidates to smoothly transition from a vocational stream to a university course. Finally, there is also a social status attached to education. Vocational education is typically looked down as something confined to the lower strata of society.

So what is the Indian government doing to solve these challenges, and how can social entrepreneurs help? And how can INAE contribute? Skill development has become a national agenda with the launch of the National Skill Development Corporation (NSDC), a public-private partnership that aims to create large, quality, for-profit vocational institutions. The initiative plans to "skill up" 500 million people by 2022. With incentives such as low-interest rates and a sizeable moratorium period, the NSDC allows social entrepreneurs to set up ventures and create social impact without facing huge financial burdens. In light of this government support, the vocational training market—valued at INR 90 billion in 2011—is slated to grow at a CAGR of 23 per cent. Hence, there are both economic and social incentives for entering the skill development space in India.

Additionally, the worldwide phenomenon of Massive Open Online Courses (MOOC) has caught up in India, and many corporations are using this platform to train people and supply the industry with skilled labour. With top universities offering courses via MOOC's and the recent prospect of setting up community colleges in India, the skill development sector brings promise to not only the Indian markets, but also the global community. [We have introduced just the words "Community Colleges". There needs to be a brief on what is their mandate, structure their inter-relations with the more formal system, their spread, how they will do what current system it is are not doing etc. This is a minimum requirement in a paper sketching out the technical education scenario]

5.3.1 Development of Technical Education System

Accessibility

The GER of 11% in tertiary education is low compared to global benchmarks. There is imbalance in the spread of institutions across the country and a large number of institutes do not have relevant accreditation.

Funding

Expenditure of 3.6% of GDP much below the planned 6% of GDP as stated under the National policy of education in 1968. Expenditure on R&D conducted at Indian higher education institutions negligible on global comparison (India 0.6%)

Quality

Lack in quantity and quality of teachers in higher education

Lack of presence in global rankings leading to low international recognition

Low involvement of academic institutions in R&D

Scenario

- India's demand for highly educated and skilled knowledge worker outstrips the supply.
- The higher education system's ability to contend with the supply constraint will thus play a major role in India's competitiveness as a knowledge economy.
- The higher education system's output in uneven.
- Quality training continues to concentrate in "island of excellence ": 80 per cent of doctorates in engineering are awarded by 20 leading institutions, while 65 per cent of doctorates in sciences come from 30 leading institutions.
- Rigid curriculum policies and lack of incentives for professors and institutions to modernize curricula lead to limited innovation in the education system.
- There is also a severe faculty constraint in academic institutions: 20-30 per cent of lecturer and professor positions are vacant. Universities have found it hard to retain good faculty, given the pay differentials in education vis-à-vis other callings..
- Enrollment in tertiary education in general is low (12 per cent) when compared with other countries and a large number of students are enrolled in disciplines that traditionally have weak links to the job market
- India's large diverse public R&D infrastructure has the potential to address the demand for scientific professionals
- The bulk of India's public R&D infrastructure is mission oriented to defense, space, and energy, with much less applied to problems of agriculture, construction, industry and health
- R &D institutions have also been acting as major hubs for development of intellectual and research capital of the nation encouraging students from across the universities and disciplines to carry out research in their laboratories.

5.3.2 Innovation

Innovation can be broadly defined to include both creation and commercialization of state-of-the-art knowledge as well as diffusion and absorption of existing knowledge.

- Innovation includes both "new to the world" commercialization activities and "new o the market" diffusion and absorption activities
- Innovative activities include products, processes, and innovation is critical driver of increased productivity and competitiveness,
- Inputs-both creation (R&D spending) and absorption (technology acquisition)-are closely and jointly associated with innovation outputs developing new product lines
- Informal efforts to create and absorb knowledge are also associated with innovation outputs

- Innovation is a means to productivity growth and higher living standards

Innovation potential in India

- The challenge of innovation in India combines a drive to move the global technological frontier, an effort to increase the speed at which global innovations enter the country, and the most pressing need-to improve prevailing practices across the entire economy.
- India would benefit from fostering more inclusive innovation by promoting more formal R& D efforts and by improving the ability of informal enterprises to exploit existing knowledge.

Out of developing countries like Brazil, Russia, China, Korea and Mexico, R&D spending per scientific article and R&D spending per patent granted is low indicating India's high innovation potential. See Fig.3.

(thousands $) per scientific & technical article 2003-04) **(million $) per patent granted**

Fig. 3 : R&D Spending on Patents and Scientific & Technical Articles

(Source: "Unleashing India's education-towards sustainable and innovative growth", The World Bank, 2007, p. 31)

Developing Innovation potential in India

Fig. 4 : Developing Innovation Potential in India

Figure 5 shows the key aspects.

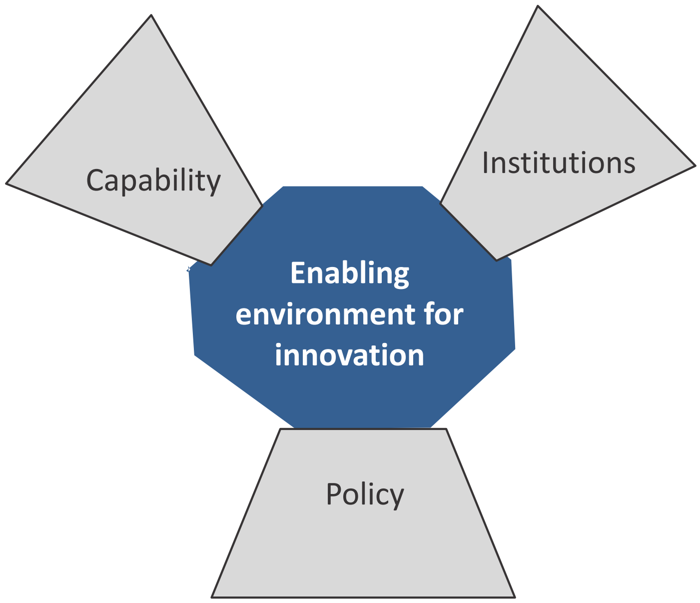


Figure 5

5.4 PROJECTED DEMAND AND DEMAND-SUPPLY GAP

Projected Demand

On a long-term basis, up to 2022, it is expected that India's GDP will grow at a CAGR of about 8%. With these growth rates, it is projected that the employment in the economy will be about 500 million by 2022. On the same basis, we estimate that by 2037 the employment will be around 900 million through the growth rate of 9% GDP. For an economy to sustain this growth rate it is essential that the workforce has suitable skill sets (could be through higher/technical education or vocation skills or a combination of both). Thus it is expected that India will be having a skilled workforce of 885 million persons by 2037. See Tables 1 to 3. In Table 1, the numbers pertaining to Industry and Science, represent largely the data for engineers. Similarly in Table 5, the data pertaining to Industry and Services is related largely with engineering and technology.

Table 1 : Projected Employment in Agriculture, Industry, and Services

Year	Projected Employment (in million)			
	Agriculture	Industry	Services	Total
2011-2012	229.20	105.00	153.50	487.70
2016-2017	240.20	126.20	189.50	555.90
2021-2022	269.67	141.68	212.75	624.10
2026-2027	281.64	168.98	253.48	704.10
2031-2032	309.70	198.53	285.88	794.10
2036-2037	344.80	229.87	309.44	884.10

Estimates projected based on 'The Challenge of Employment in India – An Informal Economy Perspective' (April, 2009)

The following table presents the share of employment in various sectors for various growth scenarios till 2037. We do not see the proportion of employment to change significantly between 2017 and 2037.

Table 2 : Share of employment of different sectors till 2037

Year	Agriculture	Industry	Services	Total
2007-08	51%	20%	29%	100%
2011-12	47%	22%	31%	100%
2016-17	43%	23%	34%	100%
2021-22	41%	23%	36%	100%
2026-27	40%	24%	36%	100%
2031-32	39%	25%	36%	100%
2036-37	39%	26%	35%	100%

Estimates projected based on 'The Challenge of Employment in India – An Informal Economy Perspective' (April, 2009) and IMaCS Analysis

The challenge pertaining to the need for skilling would be further compounded by the fact that 95% of the employment would be generated in the informal sector (as per the National Commission for Enterprises in the Unorganized Sector - NCEUS) by 2022 and 92.5% by 2037.

Table 3 : Projected share of informal employment (in million, and %)

Year	Employment (in million)			% share		
	Formal	Informal	Total	Formal	Informal	Total
2011-12	34.5	453.1	487.6	7.08%	92.92%	100%
2016-17	33.9	522	555.9	6.10%	93.90%	100%
2021-22	37.4	586.65	624.1	6%-7%	94% to 95%	100%
2026-27	45.77	658.33	704.1	6.5%	93.5%	100%
2031-32	55.59	738.51	794.1	7%	93%	100%
2036-37	66.31	817.79	884.1	7.5%	92.50%	100%

Projected based on 'The Challenge of Employment in India – An Informal Economy Perspective' (April, 2009) and IMaCS analysis

Demand-Supply Gap

It is expected that about 12 million persons would join the workforce every year, and an existing skill development capacity of about 3.4 million is thus required to be enhanced to about 15 million considering that even sections of the existing workforce would have to be trained. It is expected that this 15 million would be the required skill development capacity in vocational training in itself as a large portion of the employment (as well as workforce input) would occur in the lower levels of the skill pyramid. This is also the required skill development capacity as specified in the National Skill Development Policy.

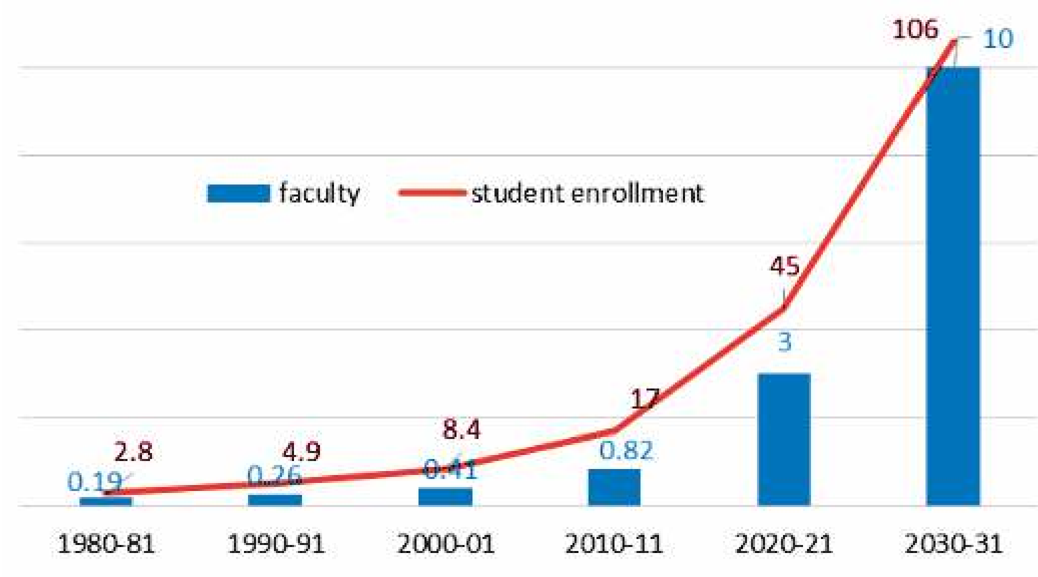


Fig. 6 : Student Enrolment & Faculty (in millions) in Higher Education

(Projected based on Human Resource & Skill Requirements in the Education & Skill Development Services sector, NSDC)

A very large proportion of the numbers in Table 3 and Fig. 6 pertain to engineering and technology.

Inherent Problems:

- After graduation, the students will most likely go into industry (which is fine for the immediate needs of industry). But they generally will not go back into teaching, which suggests a major shortage of faculty for the next generation of students who might be inclined to later go into these professions.
- One of the greatest criticisms from companies in the construction industry w.r.t engineering graduates is that they do not understand how to be a contributor to the project team. Their education does not prepare them for a team environment, solving problems as they rise by building upon the expertise and strengths of the various members of the project team. For many such a charge is nothing new while many others have incorporated real-world engineering practices in a classroom setting.
- Scope to improve INAE's connectivity and interaction with industry

Suggestions:

- One needs to look at the in-House Practical Training Program at Nanyang Technological University (NTU) in Singapore that requires each student to take turns serving as manager, office engineer, and field engineer in a "company" attempting to design, manage, and complete a specific engineering construction project. Students are required to make presentation and interact with real-world professional engineers, architects, zoning boards, and other groups that would typically be involved over the course of the project.

- Other trends that will influence our educational progress include: design-build, turnkey projects, joint ventures, privatization and other similar professional developments which are affecting the way the industry must conduct its business. We must incorporate these changes into our education system; or else the students will not be adequately prepared to serve as practicing engineers. More focus is needed in the classroom on computer skills, technology development, financial knowledge, management practices, and design talents. We need to see these focus areas incorporated into the classroom from the practitioners' perspective. The industry is changing, so rapidly that the educational process can become obsolete within five years unless it is designed to adapt and change with the business-operating environment.

5.5 INAE VISION

INAE envisions a revamp of our approaches to engineering education considering that in the new century, learning will truly be a continual process.

- Sustainability, energy efficiency, and global climate change will significantly impact how the future is being approached curriculum will need to focus more sharply on these issues.
- The planning of an engineering curriculum that ensures a sound knowledge of the basic traditional sciences, an understanding and appreciation of humanistic and social issues, and an adequate exposure to the new disciplines and methodologies, as well as emerging ones, represents a serious challenge to engineering educators. *A solution must be found through INAE as a facilitator without extending continuously the duration of engineering education and maintaining an appropriate number of applications oriented engineering design courses.*
- The pedagogy of engineering education should be changed. Engineering students prefer active teaching methods. The future engineering program should be based on approaches such as active learning, co-operative learning and problem based learning. Practical training, industrial attachment, job rotation, internship, externship can be adapted. The way engineering education is imparted is important to the future of the engineering profession in the context of the gap between the need for well-trained engineers and the ability of universities/institutes to produce such engineers.
- It is a problem that requires more time and deeper thinking than is normally available during periodic and routine curriculum revisions, and which is influenced by the background and preparation of students entering engineering schools. It is therefore closely tied to the upgrading and revision of our system of secondary education, a matter of national importance in which engineers should have a say as active members of the society.
- Massive Open Online Course (MOOC) such as COURSERA are changing and transforming the way people learn across the world. Now, these free online distance educators are showing potential to change the way students complete their courses in physical universities. We should open up to the idea of using MOOCs not just to supplement course curriculum, but also to substitute some components of it.
- Another point that deserves some consideration is the trend in some academic institutions to put excessive pressure on young faculty members to gain early recognition in a very

specialized area; this is combined with a system of values in which the amount of research funds generated and the number of publications take priority over the quality of the research and teaching efforts. Such policies may not only impair the proper intellectual development of young faculty but may also cause serious damage to the quality of engineering education, particularly at the under-graduate level. These are matters of concern to the whole engineering community as well as to individual colleges and universities if engineers are to be properly prepared to face the challenges and opportunities.

Our goal to ensure effective engineering education should be pursued within the context of a comprehensive examination of all relevant aspects of the interrelated systems of engineering education, engineering practice and the global economic system. Engineering education must be realigned to promote attainment of the characteristics desired in practicing engineers, and this must be done in the context of an increased emphasis on the research base underlying conduct of engineering practice and engineering education. This will require that action be taken by key stakeholders, particularly engineering faculty and the engineering professional societies.

There is a need to address the issues of curriculum structure and course innovation in order to meet the expectations of industry, research, students and the professionals with regard to engineering graduates of the coming decades. The curriculum should address five pillars necessary for strong higher education that are: governance, leadership, academia, teaching and learning, and research and development to ensure that the foundation for a rejuvenated higher education system remains solid in the years to come. Role of the modern engineer as technical specialist, systems integrator and change agent are also important considerations.

The engineering education system should be broad-based engineering programmes. A new engineering education paradigm in conjunction with profound cultural changes should provide the environment for the new curriculum. Our goal is to reengineer engineering education that focuses on outcome based education to make it more effective, flexible and simpler. The desired outcome should include an enhanced educational experience and opportunities to pursue engineering as a liberal education that provides the diversity and breadth needed for engineering and non-engineering marketplace. It should also depict engineering education that develops the motivation, capability and the knowledge base for lifelong learning.

The current engineering instruction typically relies upon large lectures, highly structured problem assignments, and structured examinations for assessment. The process of engineering education should change to use more effective pedagogical approaches and to engage students more effectively in the educational enterprise. Such emerging technologies, including multimedia, computer-based simulation and computer aided engineering, can be important components in the educational process along with collaborative learning, team projects and other student centred modes. Also, changes must provide improved learning environments such as active learning; collaborative learning; modular learning; research, development and practice experience for undergraduate; new physical environments, distance learning; hands-on learning; and integrative learning.

The universities, accreditation bodies and industries should collaborate in setting the accreditation criteria. Traditional methods of assessment such as student survey of course quality, accreditation processes, and the market demand for graduates should be augmented with new approaches The university should take new responsibility for promoting technological literacy and leadership role in holistic approach by integrating curriculum elements across disciplines.

The role of academic staff is to keep pace with the rapid technological development, internationalization of enterprises and globalization of world economy, so that they can produce the best engineers. They must establish an integrated system to support professional development of engineers that will cover engineering education, training and practice, professional certification and continuing professional development nationally and internationally.

Forecasting of the future is a difficult and risky task. Long-range predictions involve a large amount of uncertainty and very low reliability. Even so, efforts of this kind are worthwhile to influence and shape the future. In engineering profession we should first look at the basic knowledge and preparation engineers should acquire in order to face with confidence the problems and challenges of the future and the implications on engineering education. A number of areas which are likely to be of new or increased interest to engineers in the near and intermediate future need to be considered for inclusion in the engineering education curricula.

INAE can play a pivotal role on one hand in working with the apex bodies such as UGC/AICTE or any equivalent body that will be formed in future under the Ministry of HRD to work towards INAE VISION 2037 and on the other very closely with CII and FICCI.

5.5.1 Area of Future Interest

India has to face the grand challenges of tomorrow and have a level playing field with its counterparts from the developed nations by properly grooming its young talent so that they emerge as a strong work force to build the nation. There are a number of problem areas in which the engineering profession may be actively involved in the future. Some of these that INAE can pro-actively take forward are presented here.

INAE should work towards creating a road map for innovative educational system that facilitates:

- Revamp and revise educational system with coursework, curriculum, vocational/ practical training
- Enhance our educational programs and delivery methods
- Include topics on inter-disciplinary and trans-disciplinary areas in addition to the conventional engineering subjects
- Promote interdisciplinary teaching and research collaborations
- Provision for improved and also advanced Infrastructure facilities in colleges
- Knowledge sharing through online collaboration – webinars, blogs, virtual classrooms, etc.
- Internship programs
- Capacity building
- Inculcate probing and creative skills adapting innovative teaching aids
- Provision for more engineering colleges / technical institutions in north –east and similar other less explored
- Co-existence of engineering colleges and diploma/finishing schools

- Trade and skill up-gradation
- Innovative schemes from the Academy for improving the education
- Updating cutting edge technology in course curricula and lab experiments
- Introduction of research culture in engineering colleges
- Introduction in the use of online technologies for teaching – offering online courses including the Massive Open Online Course (MOOC)
- Provision for group work, project based learning
- Online education system to allow completion of required qualifications; this will enable the candidate to complete his profile and become eligible for job or employment; thereby increase employment opportunities
- Using modern and better teaching aids including multi-media, webinar, video- conferencing, etc.
- Industry-academia-students interaction at diploma, under-graduate and post-graduate level (periodic or continues); some of the core courses should have mandatory programs
- Facilitate adjunct faculty positions/recognition of industry staff to teach in the engineering colleges as a mandatory requirement in the core courses
- More testing and evaluation through experimental and field programs included in the course curricula
- Mediation with planning commission for increased fund allocation in engineering education.

SS6 : MANUFACTURING

6.1 PREAMBLE

The manufacturing industry worldwide, is becoming increasingly complex on account of shorter product life cycles, ever growing customer demands, the need for multilocation component manufacturing, alternative raw material and energy resourcing and multilevel marketing. North America, Europe and countries like China, India, Australia and South Korea in Asia pacific region are the leaders in manufacturing industry. Tremendous market pressures are being placed on manufacturers to continually scale down the supply chain costs, to pursue new lucrative markets in developing countries in Asia and to quicken the pace of product innovation. The manufacturing sector in advanced countries are either relocating their manufacturing activities outside their countries or outsourcing their supply chain requirements from developing economies. This trend will gain further momentum by 2020.

6.2 CURRENT MANUFACTURING SCENARIOS AND CHALLENGES

6.2.1 Global Scenario

The manufacturing sector is increasingly looking at the whole world as their market as well as manufacturing base to make the development and manufacturing costs of their outputs highly competitive. The world's largest manufacturers are creating more assets in overseas destinations than in their home markets. Nearly half of North American and Western European manufacturers either sell their critical intermediates or their final products to China. The other top five market destinations are India, eastern and central Europe, Mexico, Brazil and Canada. These pursuits are helping them to stretch their supply chains and avail the local incentives in overseas destinations. Medium and conservative large scale manufacturers are establishing their supply chains on a local basis but they are designing them from a global perspective.

Another major development that is taking place in the manufacturing sector at global level on a significant scale has been the service component. It predominantly consists of after market services, spare parts and supporting software / hardware systems. The combined revenues of world's largest manufacturing companies has reached USD 1.5 trillion with their services revenue touching 25% of their total business. There is still a large untapped potential for earning attractive profits from more innovative service businesses. The key factors for the service sector growth are competitive business strategy, operations planning and management, viable collaborative linkages, access to high tech information and speed of execution. The service business is currently a more profitable venture as compared to the primary manufacture itself.

The transition from traditional labor intensive and less automated activities to advanced manufacturing processes has been taking place at a fast pace in the developed and industrially advanced developing countries. It is aided by the information technology inputs, modelling and simulation of critical process operations, innovative supply chain management practices and implementation of sustainable manufacturing components. Since low carbon energy systems, semiconductors and new materials will provide some of the corner stones of manufacturing sector economy in the future, multiple areas of research are underway in leading technological institutions and their high risk production in the initial phases are being located in Asia pacific region. Similarly, speciality products and biological substances with novel applications are emerging as advanced technology products. Over the next 10 years, advanced manufacture will become increasingly globally linked through digital supply chain management systems. By 2030, the advanced manufacturing processes will become more energy and resource efficient with minimum supply chain risks. From engineering viewpoint, these developments will accelerate the new knowledge generation in the developing world since advanced manufacturing will become a priority for countries like China and India. They will increasingly rely on more flexible and scientifically inspired nano scale fabrication processes and assembling intermediate products by area or by volume rather than by layering techniques as is practiced today.

When manufacturing technologies are viewed in terms of their very large scale economic potential and capacity to disrupt, certain technologies emerge as front runners for future growth. Their disruptive forces can bring about large scale changes in economies, societies, demographic shifts, highly skilled manpower expansion on a rapid scale and new patterns in capital formation. Based on current engineering knowledge, twelve potential disruptive technologies have so far been identified. They include mobile internet, intelligent software systems performing knowledge tasks, cloud hard/software, intelligent robotics, autonomous vehicles, big data analytics, renewable energy storages, 3D printing for additive manufacture, intelligent materials, unconventional oil / gas exploration and grid compatible renewable energy systems. These manufacturing technologies have the potential to make direct economic impact to the extent of USD 30 trillion by 2030.

6.2.2 Indian Scenario

During the last decade, India has emerged as one of the key manufacturing centres in the world for automotive, pharmaceutical, packaging, food processing, bioproducts and textiles. The Indian manufacturing sector accounts for 17% of its GDP providing employment to more than 100 million persons. However, Indian share of the world manufacturing is only 1.8%. In contrast, Chinese manufacturing sector contributes to 34% of its GDP and is about 14% of global manufacturing. By 2020, the Indian manufacturing sector is expected to generate 25% of the country's GDP by adopting automation to facilitate greater efficiency, sustainability, global competitiveness and product / process standardization. Despite these prospects, the Indian manufacturing industry is facing severe competition from more modern manufacturing platforms emerging in Asia and South America. Increasing material and labor costs coupled with process inefficiencies are blunting the Indian competitive edge.

In fact, around 60% of India's population continues to remain dependent on the agriculture sector, sharing less than one-quarter of India's GDP. Without reforms, the agriculture will continue to suffer from endemic overemployment, low wages and monsoon dependency. This will result in continued urban migration, but without the development of industrial sector, manufacturing in particular, this will lead to rising unemployment in the cities. Thankfully, general recognition that this pattern is unsustainable is growing. It is estimated that India needs to create 7-8 million new jobs each year outside of the agricultural sector to stay at its current unemployment level of 7%. Clearly the growth of the manufacturing sector is imperative to create more jobs. With the advanced digital technologies of today, the speed of incorporating changes in manufacturing technology and processes is key to ensure that the following critical national concerns are addressed:

- Self-reliance in strategic sectors
- Inclusive Growth
- World Class infrastructure
- Energy Security
- Environment friendly industry
- Made in India Brand
- Share of global trade in manufactured goods

6.2.3 Challenges for the Growth of Manufacturing in India

The major challenges towards achieving a high growth rate in manufacturing can be summarized as below:

– Significant presence of small scale unregistered units, many of which have been created because of artificial market distortions

– Poor quality of transport infrastructure including port facilities where productivity is among the lowest in the world

– Power shortages, outages and high cost of power (50% more expensive than in China)

– High cost of capital. It continues to be 10-12% against international average of 6-8%.

6.2.4 National Manufacturing Policy 2011 (NMP 2011): Essential features

Government of India decided to come up with the National Manufacturing Policy to bring about a quantitative and qualitative change with the following six objectives:

1. Increase manufacturing sector growth to 12-14% over the medium term to make it the engine of growth for the economy. The 2 to 4 % differential over the medium term growth rate of the overall economy will enable manufacturing to contribute at least 25% of the National GDP by 2022.
2. Increase the rate of job creation in manufacturing to generate 100 million additional jobs by 2022.
3. Impart appropriate skill sets among the rural migrant and urban poor to make growth inclusive.
4. Increase domestic value addition and technological depth in manufacturing.
5. Enhance global competitiveness of Indian manufacturing through appropriate policy support.
6. Ensure sustainability of growth, particularly with regard to the environment including energy efficiency, optimal utilization of natural resources and restoration of damaged/ degraded eco-systems.

In order to achieve these goals NMP 2011 has proposed

(i) Foreign investments and technologies will be welcomed while leveraging the country's expanding market for manufactured goods to induce the building of more manufacturing capabilities and technologies within the country;

(ii) Competitiveness of enterprises in the country will be the guiding principle in the design and implementation of policies and programmes;

(iii) Compliance burden on industry arising out of procedural and regulatory formalities will be reduced through rationalization of business regulations.

(iv) Innovation will be encouraged for augmenting productivity, quality, and growth of enterprises;

(v) Effective consultative mechanism with all stake holders will be instituted to ensure mid-course corrections.

6.2.5 Casting Future Growth of Manufacturing Industry

It is suggested that in order to ensure implementation, the growth of India's manufacturing sector be viewed in three different time frames and simultaneously. That is:

2013-14 to 2020-21

Goal: GDP Growth: 7-9%; Manufacturing Contribution to GDP: 18-20%

2021-22 to 2029-30

Goal: GDP Growth: 8-10%; Manufacturing Contribution to GDP: 20-25%

2030-31 to 2037-38

Goal:GDP Growth: 8-10%; Manufacturing Contribution to GDP: 25-30%

India's expanded integration with the global economy and the Govt.'s recognition that infrastructure needs to be overhauled are likely to ensure that the trend of growth increases in the next decade.

6.2.6 Critical Actions

National Manufacturing Policy, which was introduced in 2011, may be recast to set the objectives over a longer vision of 2037-38 instead of only up to 2022.

- Growth in manufacturing sector is dependent on the favorable investment climate in terms of better infrastructure support, institutional finance at affordable rates of interest, etc. Therefore, formulating fiscal policies aimed at promoting accelerated growth of the manufacturing sector will be the need of the hour.
- Structural reforms initiated in early 1990s, despite the recent setbacks, need to be pushed urgently to enable manufacturing industries to grow on path to achieve 25-30% contribution to National GDP by 2037.
- Within next 2-3yrs issues relating land acquisition, water, raw materials mines allocation, Environment & Forest clearances need to be resolved. (these factors/impediments, have been observed as the major hurdles today in project implementation delaying the already announced large projects to be grounded.)

- Large equipment design, engineering and manufacturing companies in the Public Sector need to be set up to circumvent the danger of dumping of subsidized equipment (by China, for example).
- Long term competitive ability of Indian firms would depend on production efficiency which, among other factors, will also require ability to develop, import and adapt new technologies. The manufacturing firms have to concentrate on internal changes aimed at improving efficiency and reducing costs. CII-Mckinsey study identifies the difference in labour productivity across multiple sectors between India and China from 10% in TV assembly to 360% in footwear. Policy support to be given enhance global competitiveness of Indian manufacturing.
- Given the fast depleting material resources, increasing competition amongst nations and growing need to protect Intellectual Property Rights, India will have to strengthen its knowledge base. For this Govt. will have to address the issues relating to the institutional gaps in promoting industry-research institutions interaction, strengthening network of Science & Technology institutions and technically trained manpower availability.
- The country will have to build a robust manufacturing sector by strengthening growth potential of selected capital goods from standard factory machinery to high end technology products like aircrafts.
- In fact, there is an urgent need to achieve technological leadership in fields like machinery, pharmaceutical, transportation equipments, chemical and household equipment.
- Factors such as unique Indian history, culture and political environment are generally regarded by the industry as challenges to the growth of manufacturing success. In the present times, pillars of Indian model of manufacturing excellence will have to depend on:
  - Scientific research and vigorous R&D which will mainly be led by the urban educated youth, to fulfill the needs of industry.
  - Skills training of the rural youth (so far closely linked to agriculture) through apprenticeship system.

6.3 PROJECTED SCENARIO FOR 2037

6.3.1 Near Net Shape Manufacturing: Forging and Shaping

Many emerging technologies offer opportunities to develop structures and products with novel combinations of physical, chemical and mechanical properties for use in a wide spectrum of manufacturing sectors such as aerospace, defence, biomedical and security.

One of the core manufacturing processes, massively used in manufacturing automotive and aerospace parts known as cold forging, needs critical knowledge to design and develop the tooling and presses. In order to reduce the development time, the application of software and intelligent decision making models become a necessity with a view to achieve quicker manufacturing of the customized products.

In recent years, it is found that many light weight automotive applications require aluminium and magnesium castings with characteristics such as wear resistance, high strength and ductility. Such a complex manufacturing requires vacuum-assisted die casting with software support and many continuous and discrete simulation tools to predict inter-facial interactions of components and structural integrity to overcome the burden of knowledge intensive tasks. To realize cost effective components for their applications in automotive, aerospace, machine tools and medical equipment, it is imperative for practitioners to adopt techniques supporting intelligent processing of components.

6.3.2 Non-traditional Manufacturing Processes

Extremely hard and brittle materials, flexible or slender and complex shaped components difficult to machine by traditional machining processes such as turning, drilling, shaping and milling require non-traditional machining processes, also called as advanced manufacturing processes. Several types of non-traditional machining processes like electrical discharge machining, electro chemical machining have been developed to machine components with complex features, shapes and part geometries under improved and favourable machining conditions. Many rapid prototyping machines are being developed to produce the actual parts by layer manufacturing and deposition based techniques.

6.3.3 Nanotechnology Adoption

For the robust design of expensive nano-composite manufacturing processes to achieve the desired level of quality improvements, Carbon Nano Tubes (CNTs) are the most promising materials for next generation structural applications because of their exceptional mechanical properties and low weight-to-volume ratio. For example, a leading global manufacturer of CNTs, is already trying to enhance the practical application of Carbon Nano tubes by integrating into systems comprising polymers, metals, composites and biomaterials. It is the right time to transform and translate all the nano-manufacturing processes into technologically viable manufacturing processes to support the products used by consumers and infrastructure entities. Fabrications of several nano-devices are also in their infancy. Therefore, an aggressive effort by manufacturing experts are required to convert the discoveries in nano-technologies into nano-enabled products to be used by consumers.

6.3.4 Micro Factories

Industries including biomedical, consumer electronics, aerospace, and defence require components (under 20 mm) with micro-scaled features (between tens and hundreds of microns).These components possess intricate features and are made up of wide variety of engineering materials. Their manufacturing is very difficult as they require dimensional accuracy of the order of 10-3-10-5 mm. These challenges cannot be tackled by traditional manufacturing equipment. Moreover, there are fixturing limitations as micro-scale parts require unique movability considerations. Features like frequent recalibration and fast assembly and disassembly are required in the miniature production cell. These requirements led to the introduction of the concept of micro-factory which caused a significant reduction in cost, space, and energy requirements. There are, today, mainly two categories of manufacturing systems in which micro-factories are exploited. In the first one, desktop factories are deployed at different places whereas in the second category a group of multiple micro robots cooperatively execute the tasks.

6.4 INAE VISION FOR INDIAN MANUFCTURING SECTOR

The INAE is aware that Indian manufacturing industry is operating below its true potential. The road blocks for achieving higher level of engineering skills, infrastructure modernization and the depth of manufacture continue to be the areas of concern. The INAE has, however, noted following positives for its future growth:

- Increased commitment to enhance Indian global competitiveness in high engineering areas
- Ability to reengineer some of the current practices in basic manufacturing to usher in new transformations
- Keenness to leverage India's demographic advantage to develop a new interface with cutting edge technologies / concepts associated with nano technologies, micro factories and allied areas.
- Building new strategies to achieve higher product differentiation in mechanical, electrical, electronic, pharmaceutical and allied sectors
- Acceptance of knowledge internationalization as a strong tool to tap newer markets and enhanced capabilities to maintain competitive edge at global level.

The INAE envisions to provide intellectual supporting hand to Indian manufacturing sector in terms of technology foresight development, stronger academic-industry linkages, bringing international experts to provide new knowledge for reengineering of Indian practices and sensitizing the government of India on policy issues and incentives needed for increased future growth of the Indian manufacturing sector.

SS7 : ELECTRONICS AND COMMUNICATION

7.1 PREAMBLE

Twenty first century has inherited two revolutions and developments related to the field of Electronics and Communication, namely:

Semiconductor Technology with Scalable Devices in which Gordon Moore predicted doubling of device count in a silicon chip in 18 months on the average.

These law-triggered developments in an unprecedented scale affecting every aspect of human activities where facts became stranger than fiction. It is estimated that presently the number of semiconductor devices being printed on silicon is comparable to that of alphabets being printed in a print media indicating that with attributes of various electronics functions the impact on human civilization is destined to be on much higher scale than accomplished by printing technology.

World Wide Web (www) is the other development, which is responsible for the success of converting the world to a global village. The technology is pregnant with possibilities of establishing an inter-planetary civilization in principle. The internet revolution has set up a system for global networking and connectivity affordable to every human being.

System-on-Chip (SoC) - battery-operated devices that is portable and smart with low voltage and low powered (LVLP) integrates into a single silicon chip functions of communication, computation and consumer products. Such a tool has set platform for an era of Digital Nomads. Past few decades thanks to the development of intelligent phone, high speed communication network system and cloud computing resulted in a new world order towards globalization. It can be for seen that decades to follow points to a mobile and chip-dominated nomadic civilization as constraints of time and space (geographic location) will be outdated. Internet-of-things, point-to-point contact any time, anywhere and mobile phone with ever-increasing intelligence is destined to trigger an era of new lifestyle and mobile civilization. The footprints in the direction are already in evidence.

Above-mentioned developments in the field of Electronics and Communication have emerged as pervasive and powerful means to empower human race to evolve to a higher knowledge based civilization. For developing nations, these developments are of added and special significance as electronics and communication have proven to be great social leveler – making products necessary for daily life accessible to rich and poor at affordable cost. For emerging and developing economies, new age electronics is a great opportunity to seize in spite of formidable challenge of its development, adaptation and application for solving their staging problems.

Electronics and Communication industry is poised to overtake other areas of industrial activities such as steel, chemical, automobile etc. For all nations' industrial production, environment, healthcare, defense/security, space exploration, agriculture, employment, disaster management, government/corporate administration, space exploration, discoveries/invention, social networking, optimal sharing of natural resources etc are set to be defined by the advancements, adaptations and applications of this field.

The Technology Trend and future perspective as indicated through surveys and studies may broadly been classified in short term (~ 10 years) and long term (~ 25 years) perspective. It must be mentioned that technology forecast has proven to be disaster at times. On the other hand, such predictions have mobilized and inspired industries and researches to make things happen rather than watch things happening.

The revolution in this field centers on phenomenal progress achieved in the area of Integrated circuits and miniaturization. In this evolution past, present and future denote a pattern that indicates that technology milestones can be set in terms of time frames and technical goals.

Figure 1 gives an overview of characteristics technology drivers that dominated past five decades and was predictive following Moore's Law.

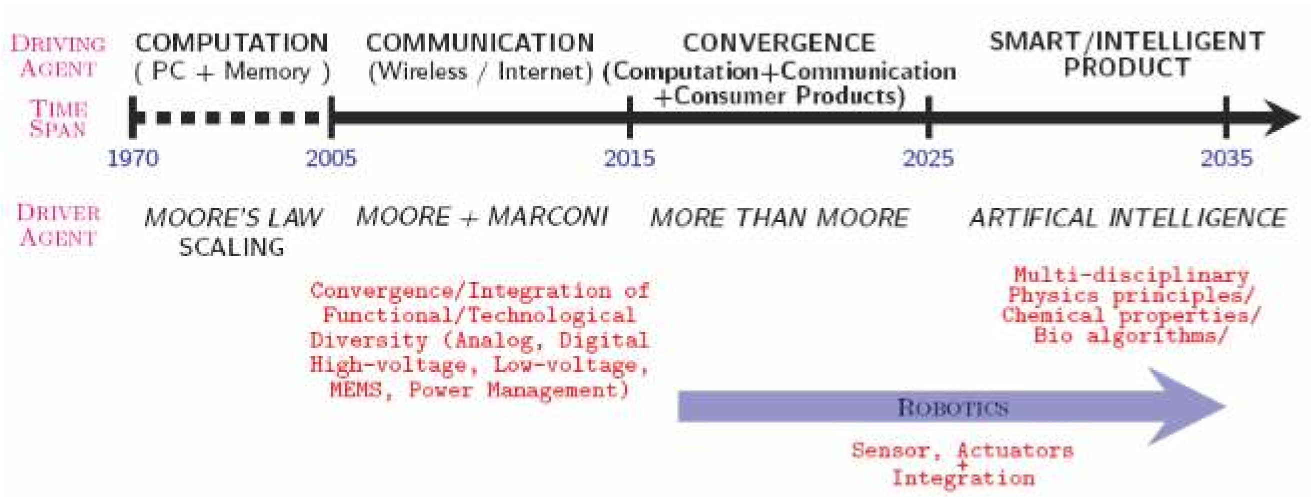


Figure 1: Micro-system evolution and technology trends

It appears future pattern of evolution can be logically forecast without the assumption of intervention of a possible disruptive technology. The decades and their prime drivers are segmented below in Table 1.

Table 1: Driver agents defining the decades in Electronics Evolution

Decades	*Driver Agents*
1965 – 2000	Scaling , Circuit-integration, Computation, PC + Memory
2000 – 2020	-networking, sensor, smart phone, SOC, RF + MEMS,3D-IC
2020 – 2040	Multidisciplinary, i/s SOC, Biochips, Artificial Intelligence, Photonics

The Metal-Oxide-Semiconductor (MOS) to Microsystems-on-Silicon (MoS) unit devices to billion transistors integrated systems development has been a remarkable tale of global industrial co-operative venture and vision. International Technology Roadmap provides the globally shared perception of challenges opportunities and initiatives.

The outline of the trends in technology and future perspective spanning covering a period over three decades to follow is divided in following broad sections:

- Nanoscale Electronics and System-on-Chip (SoC)
- Nuances of Design Technology
- New Age Electronics Technology
- Photonics and Opto-electronics Technology
- Wireless and Communication Technology
- India Amongst Electronics Nations

7.1.1 Nanoscale Electronics and System-on-Chip (SoC)

Nano-Electronics **-** Semiconductor electronics has developed to a stage where it is possible to pick and place atoms to customize functions of electronics. The nano-electronics being invisible to human eyes is being termed as the electronics of vanishing device dimensions, which indicates, to take the electronic world likely to be dominated more by materials than device properties. The shrinking size of devices approximating almost to nothingness yet becoming more and more useful takes us to the philosophical view quoted below.

The stage is set for smart materials, smart devices, smart bridges, smart transport system, smart houses and offices with embedded intelligence provided through nanotechnology.

International semiconductor community has been established a forum to evolve an International Technology Roadmap for Semiconductors (ITRS). The ITRS roadmap takes a comprehensive view of the electronics industry future regarding opportunities and challenges. The document serves as a guideline for setting up priorities. The ITRS is an output of Technology Working Groups (TWGs) of specialized aspects such as Semiconductor Technology, Design Technology, Manufacturing Technology, Component/subsystem Technology and Business processes.

7.1.2 Digital Roadmap

High-Performance MPU and ASIC product generation and chip size model is reflected in ITRS Roadmap [International Technology Roadmap for Semiconductors http://www.itrs.net]. Classical Bulk structure including extended type CMOS scaling facing a plateau, the alternative non-classical structures such as PDSOI(~ 40 nm), FDSOI(~16 nm), MG (~10 nm), Si-nano wires (~5 nm) [Richard Stevenson, Changing the Transistor Channel, IEEE Spectrum, pp 1-12, June 2013]. [SOI – Silicon on Insulator, PD - Partially Depleted, FD – Fully Depleted, MG – Multi Gate]

The roadmap projection in Table 2 is broadly based on an optimal application of scaling laws to predict key performance parameters that characterize figure-of-merit of a digital building block. Supply voltage, gate capacitance including overlap, fringing components and the current drive, determine this intrinsic delay that can be judiciously estimated against a preset target of performance acceleration. For example, the drive current governed by threshold voltage, gate oxide, capacitance, mobility are required to improve by approximately 7-8% annually to ensure annual delay performance improvement of 17%

over a period of eight years (2010-2018). Other features such as length (technology node) of microprocessor transistors is estimated to encounter a scaling of around 300%, supply voltage scaling by 30%, on-chip clock frequency to be pushed up by 350%, permissible maximum power dissipation by 15%, functional multiplication per chip by 600%. The migrating technology node, at which designs are to be implemented, is usually associated with new phenomena described by model parameters with which designers need to get continuously exposed. As technology nodes are approaching physical limits, classical physics, in inadequate to describe the device phenomena. Complex physical phenomena such as quantum effects, new scattering mechanism, mobility enhancement through strained-Si, need to be included in the classical engineering design domain. Non-classical SOI structures such as multi-gate / FinFET devices, metal gate devices, high-k dielectric gate etc. are expected to provide solution to overcome physical limits of bulk CMOS and enable progress beyond Moore. Non-classical structures are likely to be routine building blocks for the designers. The breakthroughs at material/device area are to be integrated with multi-threshold, pass transistor based circuit level approach to stretch the circuit performance limits related to complexity, power, frequency of operation etc.

VLSI manufacturing can now easily put hundreds of millions of gates or a couple of billions transistors on a single die at a reasonable cost. These manufacturing advances have enabled designers to create SOC that includes most chips/components necessary for system. SOC design teams often make use of Intellectual Property (IP) blocks in order to improve their productivity. These IPs are pre-designed components that can be used in a larger design.

It is projected that SOCs of the complexity of 40 billion transistors will be designed in 2018.

7.1.3 RF Roadmap

The communication era sparks the activity on RF micro system, the Roadmap of which is reflected in ITRS Roadmap for RF. The basic device building blocks are projected to be Extended Planar Bulk, UTB FD (Ultra Thin Body), MG (Multi Gate). The cut-off frequencies of transistors with known manufacturing solutions are projected to achieve ~ 600 GHz. The research challenge is to target ~ 2,000 GHz around year 2035.

RF evolution will be accompanied by supporting development of compound. Semi-conductor based FET and Bipolar Devices, On-chip passives components, High voltage MOSFET.

7.1.4 MEMS Roadmap

Micro Electro Mechanical Systems (MEMS) emerge as an off-shoot of Microelectronics technology realizes mechanical components on silicon. As it blessed with an already mature process technology in microelectronics the first step is to mature on the basic building blocks and subsystem that constitutes the mechanical world and the technology roadmap of MEMS in [1], outlines the future prediction of performance parameters of MEMS devices such as Accelerometers, Gyroscopes, Microphones and RF MEMS Resonators etc. Unlike digital IC revolution where digital systems built-on replication of standardized gates, MEMS world is built of diversity of basic building blocks.

While integration of electronic circuits and MEMS known as CMOS MEMS has already demonstrated products which added value to the purely electronics sub-system, the coming decades are expected to see multiplying growth of such products. The merging of electronics world with the mechanical provides a platform for development of new generations of sensors, actuators with integrated electronic interfaces, which is limited by imaginations. The penetration of MEMS based devices in automobile sector is a pointer of the potential that it has to transform miniaturization of other sectors such as aviation, healthcare, environment etc.

It is estimated that pushing the scaling 10 nm feature size of MOSFETs would be unproductive in terms of performance, such as speed, power etc. Below this technology node there has to be a paradigm shift in the strategy to enhance performance.

Chip Embedded Chip (CEC) , System-in-package, 3D-SOC are the options to develop for enhance system performance.

The *3D-SoC* is the vertical integration of chips where interchip connection and packaging are the core challenges compare to higher device integration in 2D structures. Through Silicon Vias (TSVs) promises to be the solution for enabling inter die vertical interconnect. It is expected that SoC functionality will increase on the pattern of Moore's Law even after the device scaling reach the plateau through the mechanism of vertical scaling. The design challenges of 3DIC have been identified and are projected to be solved in three generations of technologies evolutions. The 3DIC will provide the higher level of system density with heterogeneous functions, structures, materials etc.

7.1.5 System-on-Chip (SoC) for Digital Nomadic Era

Advances in Electronics, Communication and Information Technology have already resulted in life style of people which is expected to become more pervading in near future. Mobile PC, Tablet PC, Smart phones, cell phones, e-books etc are becoming integral part of life. Human civilization is on the verge of an era of digital nomads. With portable personal internet SOCs an individual can convert a location of his/her choice as home and office with day-to-day support resources encapsulated in portable digital chips. Personal internet product based development defined by computing, communication and consumer needs is set to open the gate for wide range for innovative products. The technological challenge ahead is realization of increased portability, low voltage battery compatibility, low power consumption, convergence of diversity of components such as DSP, RAM, Flash, Mixed-signal, RF, Passive and discrete components, multiple supply voltage etc. into a single SOC. The roadmap for evolution of internet personal product in decades ahead is set to target higher value of “Figure of Merit” (FOM) for the produce. For higher (FOM) for a portable internet products, it needs to have higher level of intelligence and integration and lower values for size , cost and power consumption while scaling of device size by 70% every two-to–three years as per Moore's Law is already tapering off. More than Moore in terms of functionality is projected through 3-D SOC integration.

7.1.6 Design Technology (DT)

The technology is only a means to an end. A useful and affordable product for customers is the ultimate goal for all industries. The law of usefulness states that a linear increase is useful is related by an exponential growth in system complexity.

The above is a natural corollary of Moore's Law. To be useful to 21st century customers several billion transistors on a chip symbolizes the design challenge and complexity.

7.1.7 Nuances of Design Technology

MOST (Metal-oxide-semiconductor) to MOST (Microsystems-on-Silicon) with billions of transistor is a phenomenal story of design development that remarkably addresses issues related to Complexity Management (CM) and Design Technology (DT). The SoC design complexity and challenge is increasing exponentially as two levels-system complexity and silicon complexity – both are progressing aggressively.

S*ilicon complexity* relates to processes, device structures and interconnects parasitic, electro migration, sub-threshold leakage, layout dependence, ESD, mask count, cross talk and signal integrity, IR drop, antenna effect, electro-thermal phenomena etc are the issues that gets aggravated.

The management of shear number of devices and their interconnects, layout, placement, area vs. performance trade-off, testing etc. dominate system complexity; system design can be handled only through hierarchical approach and design automation.

The other challenges related to DT are:

- Scaling related issues w.r.t. parasitics, supply and threshold voltage
- Signal integrity due to cross-talk, interference etc
- Process, voltage (supply) and temperature related variability
- Design automation
- Testing and characterization
- Cost of Hardware and Tools

A typical example illustrates the interdependence of technology node scaling factor, device count in the chip, system complexities, multiplication, technical work force deployment w.r.t. front-end and back-end design activities are illustrated through given Table 2.

Table 2 : Complexity

				Work -Force	
No. of Years	Technology Node Scaling 'S'	System Complexity Scaling factor	Device count Scaling factor	Front- end Scale factor	Back-end Scale factor
~ 10 Yrs	S = x 4	50	160	x 5	x 9

The above table indicates the fact that the billion transistor design there is a paradigm shift from device to interconnect, where process variability, electrical and physical design rules, cross-talk, antenna rule, electro migration etc are overriding considerations.

7.1.8 SOC Figure of Merit

The Figure of Merit (FOM) of a mobile personal internet product may be expressed by

$$FOM = (DIC \times I) / (S \times C \times P)$$

Where DIC = Diversity integrability Coefficient, I = Intelligence, S = size, C = cost, P = Power

An SoC belonging to the category of personnel internet product for smart (intelligent) mobile phone needs to accommodate wide range of diversity of functions related to computation, communication and consumer requirements not all of which are straightway compatible to standard

CMOS process. The diversity may related to non-standard material (such as magnetic) for FRAM, MRAM, piezoelectric material (such as ZnO, AlN) for SAW filtering, Low-k material for inter-layer dielectric, high and low voltage devices, passive components and MEMS for which additional masks are involved. For a standard CMOS process DIC=1 and for non-standard steps DIC < 1. In decades to follow, silicon complexity is expected to increase with diminishing value of DIC. It is worth mentioning that hallmark of sustainable electronics for future has to be low voltage, low power operation to make it portable. It is remarkable that taking vacuum tube electronics as reference where the supply voltage normally is used to be 200 volts today the chips are operated at 1.0 volt. So over six decades the supply voltage has been scale down by factor of 200 – a feat would not have been imagined in the era of vacuum tube electronics though one does not perceive that linear extrapolation is possible to predict that five decades later the supply voltage will be 1/200 volts. However that the chip should be operated around 0.5 volt within a decade is very much a certainty. Such a low voltage operation obviously would be possible only after many of the classical circuits architecture recast- more so in the analog domain.

7.1.9 Embedded System Design

Embedded system design is an outgrowth of cross-fertilization of VLSI technology, communication system and computational techniques. It opens up numerous application domains thereby expanding the scope of VLSI design activity. The application drives the system architecture, platform architecture, followed by hardware/software implementation involving semiconductor design and prototyping. Embedded system brings about radically new perspective in VLSI design business where conventional business model may provide space and opportunity for many new players in India [Making India Powerhouse for Semiconductor Design, Report of INAE Workshop, Oct. 31- Nov 01, 2009, IIC, New Delhi].

In overall system design, some of the key engineering trends that are emerging,

(a) Programmability in design, (b) Design at an abstract level, (c) System design verification/ validation and so on.

Validation/verification methodology of embedded system at software level is based on data structure, algorithms, etc., which have not progressed as fast as semiconductor technology. This area represents a barrier and opportunity. Given the hundreds of millions of transistors on a chip, capturing the complexity of an SOC into an executable verification environment and then performing formal verification at every step of the design flow van become a mammoth task. Modeling performance around transactions and bus functional models facilitates in creating reusable verification code. Physical verification at multiple levels is becoming a major bottleneck. Verification cost is increasing with the scaling of technology node and design complexity.

7.1.10 New Age Electronics

Wearable Electronics **-** Presently a person carries with him/her, consciously or unconsciously a storing of data, telephone and electronic gadgets/devices in a pocket that are capable of capturing images, receive and transmit signals carry out computation for pre-defined tasks and get connected to the outside physical world both at near and remote distance. The capability is only a tip on the iceberg and is set for innovative emerging electronics around wrist watch, sunglasses/eyeglasses with embedded internet and video camera, helmets, shoes, belts, T-shirts, trousers and almost anything that covers our body. *Wearable electronics* with flexible substrates (so called electronic paper), that can seamlessly fit into shapes of the body have emerged out of the concept and validation stage [Wearable Electronics and Photonics, Edited by X. Tao, The Textile institute, CRC Press,2005].

Electronic Textile / e-Textile – One of components of wearable electronic is emerging as a defined area of electronics that fuses the strengths of textile, electronics and communication and computing. This discipline holds promise to provide an advanced information technology to individuals and society. The basic principle to print , stitch, solder electronic components and sensors into cloths used by human being using yarns and fibers of the cloth and transmit/receive signals to/from environment. Clothing being an integral part of an individual baby to senior citizen, wearable electronics is projected to be all-pervasive in future. The segments of potential target users are identified as below:-

The application domains are: military (individual combat, casualty information), civilian/public (fire, earthquake and disaster management), safety (law enforcement by police), sports (fitness), space (astronauts) heath (patient monitoring and rehabilitation).

7.1.11 Photovoltaic Technology (Terrestrial and Space Driven)

The greatest challenge before the world today is to find a long term solution for the ever increasing demand of energy in the background of vanishing reservoir of existing resources of oil and coil etc. alternatives such as energy from fusion is facing increasing social opposition against this background. Harnessing solar energy from space through use of beaming via satellite is now in serious consideration. Photovoltaic devices, satellite technology, power distribution etc depend greatly on electronic systems.

Space Solar Power Satellite Wireless Power Transfer (SPS-WPT) related basic concepts have already been validated.

The constituent building blocks are:

1. An orbiting satellite to capture space solar energy
2. A satellite integrated electronic system to convert the photovoltaic generated energy to microwave power
3. A wireless transmitter to divert the microwave power to earth
4. An antenna system located on earth to receive the microwave energy
5. Electronic system to convert the microwave energy to application specific form

The principle of wireless power transfer is already a topic of research for mobile electronic systems. The use of microwave energy for industrial, medical and domestic use is well established. SPS-WPT system is a potential candidate for development of sustainable energy. Preface the issues of scaling, operational cost etc. are undertaken, the issues regarding the effect of high density microwave radiation on environment and several biological related issues have to be addressed.

7.1.12 Robotronics

Electronics has been the key activity through which mankind has pursued its never-ending journey to acquire more physical strength and intelligence. Electronics has now developed to a level of technology where tele-existence or tele-presence is not an idea but a reality. The nano-chip technology, MEMS, smart sensors associated with Real-time Remote Robotics (R^3) provides a platform for mankind to realize the dream of tele-existence. The decades between 2010-2030 are projected as the era of robotics revolution which may be more spectacular than the digital era of last three decades. The projected evolution of intelligence in robot is indicated by Hans Moravec [When will computer hardware match the human brain, CMU,2002].

Various transportation systems is expected to see a paradigm shift with "driverless" transportation system involving the use of GPS, radar and sensor. And wireless network system. All the components of technology are already proven and the stage is set for its adaptation starting with automobiles products.

It is projected that electronics products will now be customized to the needs of different age group, particularly senior citizens which constitutes increasing proportion with term as life expectancy has increased globally. Robot personal assistant (RPA) of diverse category catering to the needs of healthcare, nursing, household functions, etc is emerging as new business opportunities [Michael Hochberg et al, Silicon Photonics: The next fabless semiconductor industry, IEEE Solid-State Circuits Magazine].

Intelligent Computer for Intelligent Environment **–** Human being constantly interacts with the environment around it, with embedded memory and artificial intelligence. It is projected that it is possible to equip the environment with intelligence such that human being interacts with an environment that is intelligent enough to communicate with the human being.

Intelligent/(Smart)-SOC **–** As electronics mature and migrates to intelligent system development, biological system is expected to provide lot of insight into the physics of intelligence. Strictly the state variables in the CMOS technology and nervous tissues are analog signals. In both, energy barrier is the common parameter on which functionality is based. In terms of energy consumption, published theory estimates the efficiency of brain computation as about 3×10^{14} operations per joule, a modern microprocessor performs at about 3×10^{14} operations per joule. The challenge before the electronic system to match the biological system is to optimize on energy consumption. In the region of sub-10 nm nanotechnology the embedded chip integration will signal the era of intelligent/smart System-on-chip (i(s)-SOC). Since nano-scale MOSFETs constituting the individual cell/building block of the system-on-chip has acquired response time that is several orders faster than biological system (synapses, for instance, are endowed with response time in the range of milli seconds). With billion transistors on a chip giga scale integration has already been achieved. The scale of cell density compared to a human brain (10^{10} neuron cells and 10^{17} synapses) is a technological feat that is expected to be a distinct reality in a decade or two. The breakthrough is to be accompanied in the area of multi-disciplinary convergence of approach involving fusion of fundamental principles of physics, chemical property and algorithms governing bio-system is expected to lead to realization of brain-on-chip. The limit of progress is set not by the technology but by the complexity involved and depth of imagination.

7.1.13 Photonics and Opto-Electronics Technology

Optics and photonics have revolutionized the way we communicate, transmit and access information today. The US National Science Foundation's Committee on Harnessing Light: Capitalizing on Optical Science Trends and Challenges for Future Research [Optics and Photonics – Essential Technologies for our Nation, The National Academies Press, Washington, D.C. 2013] has highlighted optics and photonics as the country's essential technologies and states that "Optical communications networks provide the underlying high-capacity, ubiquitous connectivity that underpins the global Internet". The Internet, which is doubling in usage every 2 years, has taken over voice telephony as the largest information communication platform, all of which is based on optical fibers. According to Optical Science Trends and Challenges for Future Research Report "major advances in transmission techniques and technologies have allowed network providers to provide extremely cost-effective network upgrades that have kept pace with the extraordinary appetite for broadband Internet services … that growth has driven network bandwidth demands by a factor of 100." The current projection is greater than 100 Tbit/s transmissions for new end-to-end communication traffic by 2020. All this is possible because of the immense success of the 'dense wavelength division multiplexing (DWDM)' scheme and associated component level technologies wherein 10 – 100 Gb/s data is transmitted via each of the multiple wavelengths that get transmitted simultaneously through one single-mode fiber. This is a direct outcome of the watershed development and commercialization of erbium doped and Raman fiber amplifiers in the mid-1990s. As per the demand for optical transmission, more and more equi-spaced wavelengths are added with increasingly smaller spacing between adjacent spectral channels. As a consequence, state-of the-art components with tighter specifications such as narrowband (0.5 nm or even smaller) optical filters are required using which data transmission rates of 5-10 Tbit/fiber become possible. A growing video component in information necessitates higher data transmission rates in the present and immediate future. Current cutting-edge networks are constantly innovating on ways to absorb the ever-increasing demand for larger and larger transmission bandwidths. Some of these involve the use of existing fiber platforms in conjunction with ever-more-sophisticated modulation techniques that encode information optically along with wavelength-, time- and polarization division multiplexing (WDM, TDM and PDM) [http://www.photonics.com/Article.aspx?AID=54277]. Space division multiplexed (SDM) transmission over and above the aforementioned multiplexed DWDM transmission modes is the newest buzzword in telecom. A concept with the potential for wide commercial deployment in real world systems, which is still under development, is a single-fiber with multiple cores, each being a single mode fiber in itself within a common cladding. A critical design requirement involves their placement in terms of overall fiber geometry in order to avoid signal cross-talk between these fibers. SDM is expected to effectively address the current bandwidth crunch. Another widely discussed alternative involves mode-multiplexed transmission that would involve the use of multimode fibers, in which a few signals would be transmitted via some of the higher order modes in addition to the fundamental lowest order mode (commonly exploited in single-mode fibers). A major challenge in implementing this scheme is the current lack of appropriate components for launching specific modes.

The motivation for pursuing the field of optoelectronics is,

1. The science and engineering of light have enabled dramatic technical advances
2. Globalization of manufacturing and innovation has accelerated; and
3. Optics and photonics have become established as enabling technologies for a multitude of industries that are vital to our nation's future."

According to a study commissioned in 2010 by the Office of Science and Technology Policy (OSTP, USA) the economic impact of lasers in terms of size is nearly $4 trillion in the telecommunication, e-commerce and information technology sectors – a mind boggling number! .

Though a plethora of photonics related scientific and industrial activities have grown at a rapid pace all over the Indian subcontinent, a concerted and coordinated developmental effort is yet to take place. As the commentary states, "…a large proportion of the optical fiber communication links installed around the globe is owned by Indian companies — a fact well-known to the business community but possibly less known to the scientific community. A paradigm example of this is the Fiber-Optic Link around the Globe (acronym FLAG), a 28,000-kilometre-long submarine optical communication link between Europe, Asia and the USA. Bharti Airtel is a leading global telecommunications company that operates fiber links in 19 countries across Asia and Africa. Tata Communications, whose fiber cable network exceeds a total length of 232,000 km, is India's largest provider of data centre services and is a leading global provider of long-distance communications"[http://www.fraunhofer.de/en/htm]. The office of the principal scientific adviser to the Prime Minister of India has launched an integrated photonics research initiative that aims to promote innovative research ideas. As of now, not much information is available in the open literature regarding this initiative.

In order to make a concerted effort and launch an Indian national initiative it is very important to draft a roadmap by forming a committee with representations from the IITs, national academies including those on medical science because Biophotonics is emerging as a very important and active field of research with many imminent applications on the horizon like optical coherence tomography, biomedical imaging and its interpretation, opto-acoustic imaging, and so on, many of these have evolved as an offshoot of optical fiber technology.

7.2 WIRELESS AND COMMUNICATION TECHNOLOGY

Connecting whenever, wherever, with whomever..., - feature of nomadic communication.

7.2.1 Trends in Wireless

The content on the Internet has been growing exponentially. This is largely driven by popular applications like online social networks, video-on-demand, online learning, online gaming, etc. Matching advances in the device technology have provided the computing and communication system and application designers with huge amounts of processing and memory resources to build powerful, yet compact and energy efficient, user terminals. This growth is particularly striking in the mobile communications sector. An increasingly larger fraction of the Internet traffic has been attributed to mobile devices. Significant advances in the capabilities and sophistication of mobile devices like smart phones and tablet PCs have greatly enhanced the variety of applications and quality of content that these mobile devices can support. For example, today's higher-end smart phones provide high-quality displays for video-on-demand. The mobile devices are expected to become more and more efficient, smart, and versatile.

Mobile cellular networks and wireless local area networks (WLAN) have spearheaded the spectacular growth that the wireless industry has witnessed in the past decade. The physical layer capabilities in wireless transmissions in these networks have seen phenomenal growth in the last decade. The data transmission rates in these wireless technologies have increased over a 1000 times in the last decade and a half. A mere 13 Kbps data rate in second generation (2G) cellular (e.g., GSM) has increased to more than 10 Mbps in the fourth generation (4G) cellular (e.g., long term evolution – LTE). Likewise, data rates in WLANs (WiFi) have increased from 10 Mbps (IEEE 802.11b) to more than 1 Gbps (IEEE 802.11ac). This Moore's law driven growth in wireless data transmission rates have played a vital role in supporting high data rate applications like video streaming, etc. over wireless. Physical layer techniques like orthogonal frequency division multiple access (OFDM), multiple-input multiple-output (MIMO), and advanced error correcting codes like turbo and low density parity codes (LDPC) have significantly contributed to achieving increased power and spectral efficiencies of wireless transmissions. More recent developments in smart multi-antenna technologies and millimeter wave communication technologies are driving the wireless transmission rates and efficiencies even higher.

The wireless spectrum used in cellular and WiFi networks (900 MHz, 2 GHz, and 5 GHz bands) are getting overcrowded. In order to meet the demands of future wireless growth, higher and higher data rates need to be supported. Several approaches are being considered for this purpose. One approach is to increase the spectral efficiencies of wireless transmissions (measured in bits per second per Hz of bandwidth used) in the existing bands, and another approach is to open up and develop RF devices and technologies in unused bands. Yet another approach is to shrink the cell sizes (e.g., femto cells) and exploit spatial reuse through efficient interference management techniques.

7.2.2 Large MIMO Technology

In the first approach, use of large number of antennas in base stations/access points and communication terminals is being recognized as a promising and viable approach to push more bits per second (bps) per Hz of bandwidth. Use of large number of antennas has the potential to take the spectral efficiencies to tens (and even hundreds) of bps/Hz. The spectral efficiencies achieved in current wireless systems are only few bps/Hz. Recently, such large multi-antenna wireless systems, also referred to as large MIMO systems, massive MIMO systems, and higher-order MIMO systems, are getting researched and developed. Several large MIMO test beds are being developed and tested in universities and industry. An emerging architecture for future cellular wireless is to use hundreds of antennas at the base station and one or more antennas at the user terminals. This architecture is being investigated for fifth generation (5G) wireless standard. Challenges and great opportunities remain in the area of large MIMO signal processing, design of compact multi-antenna arrays, and efficient RF chains.

7.2.3 Millimeter Wave Technology

In the second approach, significant efforts and progress have been made in opening up and exploiting millimeter wave frequencies from 30 to 300 GHz, corresponding to wavelengths from 10 mm to 1mm (mm-wave). In the past, RF front end technology for frequency has been expensive and bulky, and hence there was limited commercial interest in using them. This has changed in recent years due to the growing availability of low-cost silicon RF integrated circuits (RFICs) in these bands. In particular, the 60 GHz band (from 57 to 64 GHz) has received the most attention. Most of this band is unlicensed worldwide. The availability of 7 GHz of unlicensed spectrum (much more than the bandwidth in current cellular and WiFi systems) opens up the possibility of devising wireless links operating at multi-Gbps rates. This opens the possibility of supporting new generation high-speed wireless Internet applications. Sophisticated beam-forming and interference avoidance techniques using narrower and high gain beams using large antenna arrays become feasible with mm-wave technology. IEEE 802.11ad standard is being standardized for WLANs operating in the 60 GHz band for indoor wireless applications. More recently, frequencies near 30 GHz are being tested for outdoor cellular communications. The results are encouraging and more studies and investigations are on to exploit mm-wave frequencies for cellular mobile communication. Multi-gigabit wireless back haul is another potential application of mm-wave communication systems and large MIMO systems. Transmissions in the mm-wave frequencies experience high attenuation due to blockages due to human movement, walls, rain etc., which is an important issue that needs to be addressed in the design of mm-wave systems.

7.2.4 Femto Cells

In the third approach, increased capacity in bps/Hz per square kilometer is achieved through the use of very small cells (e.g., femto cells). Small cell sizes have the advantage of increasing the system capacity multifold due to increased spatial reuse. Careful inter-cell interference management is essential, however. Cooperation between base stations can be exploited for interference management through multi-cell pre-coding techniques. Small cell sizes result in a large number of base stations. Therefore, the back haul requirement for communication between base stations becomes an important issue. Also, issues related to interworking with different cell types (macro, micro, femto) need careful consideration.

7.3 GAPS, OPPORTUNITIES, CHALLENGES

India, with a 125 billion population, provides a market and potential that is obviously a matter of paramount importance to all nations. The availability of rich human resources with a strong technical infrastructure for technical education is of added importance. Yet, the huge gap regarding technology ownership in Electronics and Communication is a historic reality. India has a long journey ahead to be amongst leading nations dominating the field of electronics and communication.

For the near future, the capability and competitiveness of India can be assessed from the document on National Telecom Policy – 2012, Ministry of Telecommunication and Semiconductor Development Program, Information Technology, Government of India.

The salient points may be summarized as below.

1. Telecommunication has been considered as an agent to empower the country for an inclusive knowledge based social and industrial development.
2. It is proposed to increase the rural tele-density from the present level of 39 to 100 by the year 2020.
3. Provide affordable and reliable broadband-on-demand to 600 million by 2020.
4. Provide e-governance in key sectors such as health, education, skill development, employment, banking etc. that shall be indispensable for a country with billion plus population with uneven regional development.
5. Department of Electronics and Information Technology is emphatic on the objective that both economic and strategic consideration are overwhelmingly compelling towards development of semiconductor manufacturing capability in India.
6. The economic opportunity are illustrated by the data that in Telecom products market is expected to grow from present value of $ 3.3 Billion Dollars to $ 30.0 Billion Dollars, information technology/other automation from $ 2.1 Billion Dollars to $ 10.0 Billion Dollars.
7. Consumer Electronics from $ 0.43 B to $ 1.8 B. Automotive/ industrial 0.8 B to 6.9 B.
8. Presently 99% of semiconductor chip requirements are met by import and it is growing annually by 22%. By 2020 the estimated import bill on semiconductor is around $ 46.0 – 70.0 Billion Dollars.
9. Indian healthcare industry is expected to become a US 280 Billion industry by 2022. [Preview Wafer House Coppers Report, Healthcare In India : Emerging Market Report 2007]
10. India has unique advantage to become a superpower in VLSI Design in view of:
    - ✓ Almost all leading semiconductor companies have design centers in India called “India Captive”.
    - ✓ India captives take advantage of skilled and low cost workforce providing 100 % cost

advantage through India operation.

Using the ITRS criterion [1], the design labor cost is given by,

Design Labour Cost = (Labour Unit Cost x Design Complexity) / Designer Productivity

where the labor unit costs is given in terms of compensation dollars per engineer-year, design complexity (in terms of the amount of behavior or devices in a chip) and designer productivity (in terms of the design complexity that an average engineer can fully design in a year). The cost advantage of a implementation of design in India is illustrated through figure 6 is given below.

11. Market for the third party chip design services alone is estimated to be 400 millions presently.

    Fab-less Design approaches provides a route to compete internationally in product development in spite of huge gap at present.

12. Social Microelectronics providing low cost industry environment is unique opportunity.

7.3.1 Design Ecosystem

The major elements of design ecosystem, namely, domain, EDA software support and potential domestic demand do exist in the country. Yet, we have not so far been able to leverage this design ecosystem well enough, perhaps due to (i) emphasis thus far on offering design services and not exploiting the potential Indian market, (ii) local industry operating in specific domains not showing enough enthusiasm or courage to do their system-level product design incorporating their own proprietary semiconductor design, (iii) lack of intense investment in R & D, particularly in industry and somewhat tight fisted approach of the Government in respect of liberal R & D support to the industry in the private sector including the much deserving start-up companies, (iv) absence of intense industry-academia interaction (where is our Boston?) and very importantly, (v) absence of natural agenda for this critical/strategic and economic activity. Various ecosystem elements are prevailing in the semiconductor industry- development ecosystem, manufacturing ecosystem, supply-and-demand side ecosystem, Business/Govt./Policy-related ecosystem.

India cannot skip manufacturing completely. The manufacturing ecosystem could be subdivided into

(i) Fab-related ecosystem and

(ii) System-related manufacturing that definitely needs to be developed and, in fact, to be considered as a pre-requisite for having semiconductor fabs in India.

With Special Incentive Package Scheme (SIPS) policy of govt. of India, fabs are starting for solar photovoltaic cells. This is a good start before we go for full-fledged semiconductor VLSI fabs in India. However, in this report, we concentrate on the ecosystem that enriches semiconductor design process. Focused actions on design related issues alone can pay rich dividends even after we have the highly capital-intensive manufacturing. System level and ODM companies are significantly less in India. Acceleration of electronic equipment design and manufacturing in India would promote direct chip consumption. Figure 2 shows constituents and example companies that are part of the design ecosystem.

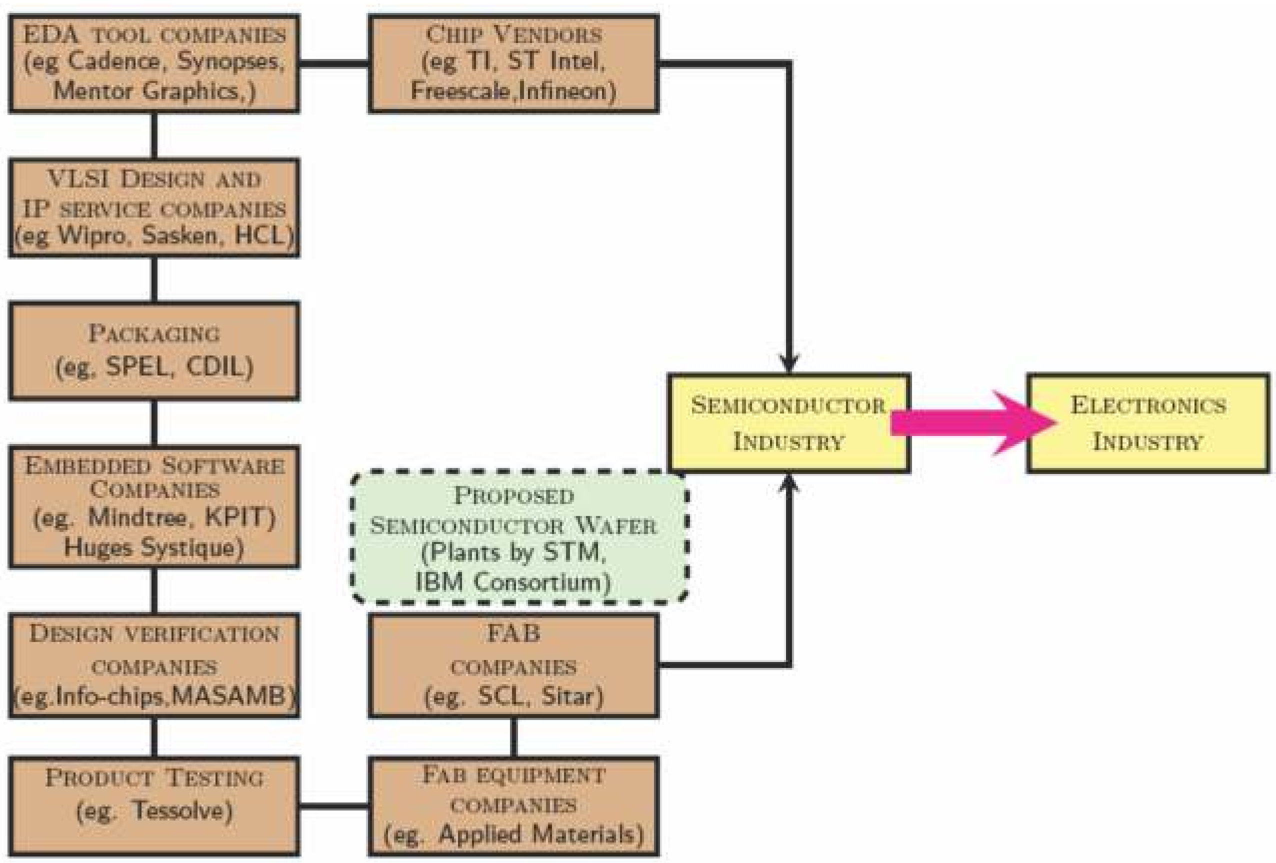


Figure 2 : The Indian Semiconductor Ecosystem

7.3.2 Quality Interaction among Stakeholders

Leveraging the design ecosystem could be lead to needed proliferation of _ables companies. This is particularly possible if Govt. comes up with design parks and provides necessary infrastructural support. EDA companies can allow pay-per-user licensing to stimulate design activities. Decision making in most existing design companies in India being done overseas, a startup company capable of developing Ips and any glue tools finds it normally difficult to sell its ware to these design companies. More complete designs locally done will help strengthening the ecosystem.

7.3.3 Environmental Conditions

As part of the ecosystem, regulatory agencies need to address electronic-waste management and simultaneously measure SAR (Specific Absorption Rate) and waste materials effect on human body. In the design stage, environmental considerations can be captured; but more serious monitoring will be needed when we start to manufacture products locally.

7.3.4 Photonics/Optoelectronics Opportunities

The field of optoelectronics/photonics and optical communication is an area of immense opportunity and challenges.

Integrated optics and silicon photonics are based on the both are the candidates for *Optical SoC*, which will be a development along the line of *Silicon SoC* .

7.3.5 Silicon Photonics

Though Silicon is genetically (structurally) handicapped to provide optical sources. The unit processes of fabrication of silicon based chips are ideally suited to implement integration of optical components. There is a new opportunity to merge the electronics and photonic system on a common/integrated platform [Diana Merculescu etal, Electronics Textiles : A Platform for Pervasive Computing, Proc IEEE, vol 91, pp 1995-2018, 2003].

Silicon photonics is an exciting area of new dimension as Plank's constant world handshakes Moore's micro / nano circuits. Germanium-Silicon structures offer the prospect of monolithic silicon photonics, which is the target frontier to reach. A more short term development that may mature hybrid integration of silicon and photonic components in a single package may provide a platform that will accelerate development of entirely silicon photonic structures. For Silicon photonics to mature a new generation of process integration, packaging technique, EDA tools, process development kits (PDKs) etc have to be developed. It appears that in the development of Silicon photonics priority needs to be given not in the pursuit of scaling of dimension of devices but in innovating means to make electronics and photonic components closely compatible.

7.4 SUGGESTIVE INITIATIVES

7.4.1 Electronic Technology Roadmap for India

Technology Roadmap for Semiconductors-India (TRS-I), which is all pervasive in modern time – is an imperative requirement, for the technological sovereignty of a country is determined by ownership of technology that empowers its continuous up-gradation and innovation necessary to be internationally competitive.

INAE can take pro-active role to interact with stake-holders such as govt., industry, manufacturing sector, research organization and academics etc. to work out a India specific roadmap to define opportunities, roadblocks, challenges etc. with dynamic updating. It needs to be a permanent feature for planning and policy making.

7.4.2 National Coordinating Organization for Electronics

An initiative on the line of countries forming the silicon conclave (Si-7) as illustrated in Table 7 is suggested to co-ordinate promotional measures for semiconductor design prototyping, characterization, packaging etc for education, R & D sectors, entrepreneurs, industries etc. in the mode of Public-Private-Partnership (PPP).

7.4.3 Photonic initiative

Similar to governmental nano-initiative in photonic development should be given attention, as it is an integral part of modern communication system. India has pockets of excellence in universities, Govt. research labs and industry the efforts of which needs to be integrated to make them visible international players in terms of education, research and production. The steps necessary for the development of optical communication is summarized in the figure.

7.4.4 Societal Microelectronics and India Specific Products

Domain and product development – Indian semiconductor activities is more service-provider oriented than product development. Also, domain expertise is a critical need to be amongst global leaders.

Right-to-Education (RTE), healthcare, environment, disaster management, governance sharing of natural resources etc. are areas where electronics and communication can play a leading role in providing an inclusive national development.

Product Positioning is an important part of strategic planning. India with its diversity and uneven regional development, glaring economic disparity has a daunting task ahead, Indian Electronic development strategy must address issues specific to country.

Societal Microelectronics would define wide range of products that is India-specific.

Table 3: Indicative India Specific Products, related to Societal Microelectronics

Sectors	*Indicative Products*
Right-to-Education (RTE)	Low cost Laptop, e -reader, smart books, smart phones with desktop capabilities, internet connectivity
Healthcare	Gluco-meter, Hand -held ECG monitor, Saliva and breath analyzer, ultrasound diagnostic bio-chip for early detection of diseases. Point-of-care devices(Lab-on-chip) – Smart card for Healthcare Insurance, mobile clinic, telemedicine cart etc
Environment & Sharing Natural Resources	Wireless Sensor Network, Electronic Nose, Gas Sensor, Emission detection and control
Security	India's Indigenous Microprocessor, FPA, Infrared detector
Disaster Management	Pick and play portable IT system, Energy efficient conversion, Energy harvester, Solar Inverter
Governance	Smart card , UID
Language/Ethnic Diversity	Language specific service product, programmable software driven Personalized product
Food/Agriculture	Milk analyzer, pesticides, detectors, moisture/humidity sen sor, Vegetable/food preservation, water pollution (e -tongue)

7.4.5 Electronics for Societal Microelectronics

Technological revolution that is taking place in electronics so dramatically is bound to effect traditions, lifestyle, social structures norms and regional developmental patterns [VLSI The Technological Giant and The Developing Countries, Proceedings IEEE, 1983]. Human response has a much larger time constant. There lies the seed of conflict in adaptation of rapidly changing technology uniformly across all cross section of society and region. On the other hand, technology has all the ingredient of being an agent of universal empowerment. Regional developments have so much of diversity that grafting a generic technology mechanically across the entire spectrum of diversity is prone to be inefficient, ineffective and at times inappropriate. Technological implementation for harmonious forward movement of human civilization must be aware of laws of social science and be flexible.

For technology to be an integral part of an inclusive and equitable regional growth, there is urgent need to produce Societal Technology Aware leaders, who are required to be sensitive to social and regional problems and concurrently have insight of the emerging technology as an agent of social transformation, and are innovative to identify and implement appropriate technology. Traditional education in technological disciplines, as it exists today is skewed with respect to emerging development dynamics.

It is appropriate that while forecasting technology trend for future decades, the need to review and innovate the educational component is also addressed. It is proposed that a top-down exercise is carried out initially, so that the scope is focused and scale is practical. Along with the technology tracking and development vision, it is necessary to address the issue of generation of new brand of technology leaders to harness the full potential of emerging technology.

Doctoral level research has the highest potential to produce technology leaders. Electronics and Communication further is the segment where innovation is urgent as the area has proven to be all-pervasive. Sensitivity to societal needs should not be taken for granted and social context should be a part of research and development program.

The salient features of the doctorial level program promoting societal microelectronics development is broadly outlined below [Model on the line of “Taoyaka” Education Program, Hiroshima University]:

Duration:

- Five Year Dissertation Program
- Domain specialization
  - Reverse cultural innovation (social science)
  - Reverse Innovation (low-cost technology)
  - Solution Implementation (Team execution including social science, technology and management candidates)
- In-house courses executed at Universities (02 years).
- On-site internship and project/dissertation implementation supported by govt., industry, universities(03 years)
- Evaluation parameters “Quality assurance” reverse innovation, societal relevance, team effort, output.

7.5 CONCLUSION

- For VLSI related products population provides both *market and opportunity*. India being the second largest populated country in the world logically has the opportunity ahead to capitalize.
- It is a paradox that more than 100 years ago it was Sir J.C. Bose who was amongst the early patent holders in the world, in the area of solid-state device in the form of Galena (PbS) point contact metal-semiconductor diode for detection of radio waves (U.S. patent 75540, 1904). It is a rare coincidence that Sir J.C. Bose also happened to be credited with recognition that J.C. Bose, independently of Marconi, demonstrated wireless communication. India happened to

be one of the earliest countries to embark on manufacturing of transistors through Bharat Electronics. Yet the fact that India is not amongst manufacturing nations of electronic products narrate the story of missed opportunities in the part. No developing nations are blessed with the path breaking research in the area of photonics such as pioneered by Sir C. V. Raman and S. N. Bose. Lessons need to be taken that application of basic research has been ignored dismally leading to technological subjugation.

- Electronics and Communication is intimately linked with economically strategic sectors such as nuclear energy, space technology etc the progress which will also be seriously affected if development of electronics and communication are not at the cutting edge.
- Indian I-T sector as a global industrial force demonstrates that India can etch a place for herself as a Powerhouse of Semiconductor Design Technology also. During the decade there has been positive and forward looking govt. initiative for development of human resources specific to semiconductor design such as SMDP (Special Manpower Development Program) and NPMASS(National Program on Micro and Smart Systems) and setting up of technological institutions(new IITs, NITs etc). The recent semiconductor policy is expected to promote investment of the order of 50,000 crores of rupees in near future with consortium approach in semiconductor manufacturing, involving global semiconductor players like IBM, STMicroelectronics, Tower Semiconductors, Silterra.
- A large number of experts of Indian origin have contributed greatly to the development of semiconductor know-how, who has settled mostly in United States. Involvement of this talent for the resurgence of communication and electronics technology in India will be logical initiative which will benefit both the countries.
- Application rather than abstraction and investment in research need to be priority to bridge the gap and strategize a sustainable growth.
- The nations that can handle complex multi-disciplinary and globally interactive activity nurtures innovation and provide an environment for shortest time-to market for a product are the ones.

Technological sovereignty holds the strategic key for India in order to realize a sustainable growth in electronics which has to be earned.

SS8 : ROAD

8.1 PREAMBLE

Road Transport is vital to India's economy. As a part of the country's transportation sector, it contributes 4.7% of India's gross domestic product, in comparison to railways that contributed 1%, in 2009–2010. Road transport has gained in importance over the years despite significant barriers and inefficiencies in inter-state freight and passenger movement, compared to railways and air. The government of India considers road network as critical to the country's development, social integration and security needs of the country.

In this respect the problems of a developing country like ours, are in many ways, different compared to those of the more industrialised countries of the west. These countries turned the corner towards industrialisation half a century before India, and had built the major part of the needed infrastructure decades ago. Most of these countries had the advantage of having done this at a time when the demands were comparatively less, and nowhere as large as the demands India faces today. As the following sections indicate, the present state of India's road network leaves much to be desired, both in terms of quantity as well as quality (not explicitly mentioned herein).It is an uphill task to cover the yawning gap. A road map is needed to be developed and implemented, taking into account the indigenous constraints and resources, by and large, while imbibing whatever is possible from the global experience.

8.2 ROADS IN INDIA – PAST TO PRESENT

At the time of independence in 1947, India had a reasonably good railway system, a few major ports, and a poor yet serviceable road network, which formed the transport system. The country moved slowly at growth rates of 3 to 3.5% up to 1980 and slightly higher growth rates of 5 % during the 80s. Following the economic liberalization in 1991, the growth rate of GDP has always recorded between 5 to 8% until 2011. During the late 90s, the GoI has introduced National Highway Development Programme (NHDP) to augment the NH network in the country and several states have taken up projects to augment state highways with financial assistance from international multi-lateral funding agencies. As a result, the length of National Highways has grown from 22,000 km in 1951 to approximately 72,000 km in 2011.The Indian Roads Congress Vision Document 2021 for Roads, envisages a length of 80,000 km for National highways – a length almost certainly expected to be exceeded. The road network has increased tenfold from 4 lakh km in 1951 to 42 lakh km in 2011. Consequently, India now has the distinction of having the second largest road network in the World. The total length of classified road networks in India at the end of March 2011 was at 4.7 million km as per basic road statistics of India, of which only 53.8% are paved. India's road density averages about 1.42 km of road length per square km accounting for 85% of passenger traffic and 65% of freight traffic in India.

8.2.1 Road Network – Existing Situation

8.2.1.1 *Strategic Roads*

The National Highways are the backbone of the road infrastructure and form the main road network in India. They carry most of India's freight and passenger traffic. State highways and major district roads constitute the secondary and interconnecting roads in India. National highways constitute about 2% of all the roads in India, but carry about 40% of the total road traffic. The majority of existing national highways are generally the undivided two-lane roads (one lane in each direction), though much of this is being expanded to four-lanes, and some to six or eight lanes. Some sections of the network are toll roads. Over 30,000 km of new highways are planned or under construction as part of the NHDP, as of 2011.

The total length of the National Highways network was around 72,000 km in 2011,as mentioned above, whereas length of roads having similar function in other developed countries are significantly higher. The Table 1 shows the comparison of length of strategic highways in selected countries.

Table 1: Comparison of Road Lengths in Countries

Sl No.	Country	Length of NH (kilometres)	Kilometres per thousand people
1.	INDIA	72,000	0.069
2.	USA	351,428	1.4
3.	CANADA	103,000	3.1
4.	JAPAN	61,730	0.49
5.	GERMANY	53,010	0.64

8.2.1.2 *Rural Roads*

Despite the impressive growth in last two decades, more than 50% of the villages are not yet connected by all-weather roads. This remains a major stumbling block for the socio-economic development of the country. As a result, the Government launched Pradhan Mantri Gram Sadak Yojna (PMGSY) in 2000 with a clear objective to provide connectivity to villages through good all-weather roads. PMGSY is the largest rural roads development scheme and aims to build or upgrade roads to all villages of a population above 500 for plain regions and those with a population above 250 for hilly and tribal areas. For the financial year of 2011-2012, an amount of 20,000 crores was sanctioned by the government for the rural roads. The Rural Roads Vision Document 2025 envisages a length of 1,400,000 km for rural roads, which may be expected to saturate the needs, and may not increase much by 2037.

8.2.1.3 *Urban Roads*

Public transport is the predominant mode of motorized local travel in cities. Historically, the public transport in urban areas was handled by network of buses (public and private sector), Auto Rickshaws, Taxis and Cycle Rickshaws and all these are road based systems. Since commuter rail services are available only in the seven metropolitan cities of Mumbai, Delhi, Chennai, Kolkata, Bangalore, Hyderabad and Pune, dedicated city bus services are known to operate in at least 25 cities with a population of over one million.

Intermediate public transport modes like tempos, auto-rickshaws and cycle rickshaws assume importance in medium size cities. However, the share of buses is negligible in most cities as compared to personalized vehicles, and two-wheelers and cars account for more than 80 % of the vehicle population in most large cities.

The suburban rail exists in seven cities only as indicated above. The supply of public transport services and urban road infrastructure have also fallen short of requirements in case of most of the cities. As a result, the congestion on the roads has increased beyond acceptable limits, leading to delays, frustration, economic losses and high pollution. Due to the poor supply and inefficient operating conditions, modal split in favour of public transport is on the decline.

As India transforms itself from an agrarian-based economy to an industrial economy, the people from the rural areas will tend to migrate to towns and cities in search of jobs and better standards of living. Percentage of people living in urban areas in 2001 was about 28 per cent and this figure is expected to reach about 40 per cent in the year 2030. This increase in urban population is a serious cause for concern to the highway professional since movement of increased number of people for work, education and other types of trips is going to cause more and more congestion, delays, accidents, energy consumption and pollution. Annual passenger and freight movement in urban areas is expected to increase about 50 % from 2001 to 2031.

One of the major concerns in road-based transport is the carbon emission it produces. However, due to improvements in vehicle technology, studies have suggested that total CO_2 emission per annum in 2030 will be similar to emission levels in 2001. Even then, the phenomenal increase in passenger movement from road-based vehicles in urban areas would be clearly unsustainable in many ways. Already, the urban road traffic scenario in every town and city is chaotic, exhibiting severe congestion, delay, fuel wastages and pollution. With a 50 % increase, the situation will become unmanageable.

8.3 CURRENT TRENDS AND PLANS

8.3.1 Government and Industry Interventions

With the government permitting 100% Foreign Direct Investment (FDI) in the roads sector, most foreign investors have formed consortiums with Indian companies to participate in the development and implementation of road projects in the country. The construction companies are now being rewarded with large portfolios of BOT projects. Many states, have formulated enabling policies, and also established PPP cells to facilitate private sector participation in key road projects.

In addition to the policy benefits, the government has announced several incentives to attract private sector participation. These include government's initiatives and distinct roles to bear the cost of the project feasibility study, land for the right of way and way side amenities, shifting of utilities, environment clearance, cutting of trees, etc; duty free import of high capacity and modern road construction equipments; declaration of the road sector as an industry; easier external commercial borrowing norms; right to retain toll; increase in the overseas borrowing limit for infrastructure sectors to USD 500 million from USD 100 million; and full exemption from basic customs duty on bio-asphalt and specified machineries for use in the construction of national highways, and many others.

8.3.2 Strategic Connectivity

The Government of India plans to construct 35,000 km of highways by 2014 under the National Highway Development Project at an investment of USD 60 billion. The Ministry of Road Transport & Highways has also recommended, in the Twelfth Plan, a total expressway network of about 18,637 km to be built in the country for the unhindered, high-speed and safe movement of traffic for both passenger and freight, along the high traffic density corridors based on the philosophy of 'access controlled toll facilities'. Construction work on the country's expressways will be taken up in three phases, and is scheduled for completion in 2022.

The scope for expanding the National Highway network, beyond the present 2.0% of the total network, has been considered in the Twelfth Plan. As part of the targeted programme, the single and intermediate–lane national highways would have to be upgraded and augmented to two-lane standard. In addition, a new programme for construction of roads in the North East was also taken up in the Eleventh Plan, including the proposed Trans-Arunachal Highway. The completion of this network in the North East, along with road connectivity to Myanmar and Bangladesh will help open up this route to mutually beneficial economic cooperation with other neighbouring countries in the Southeast Asia.

8.3.3 Rural Connectivity

The government has announced plans to adopt the public-private-partnership model (PPP) to execute the PMGSY more efficiently and to accelerate the building of rural roads. Under the PPP model, private developers are allowed to design, develop and maintain the project for a stipulated number of years before the government takes over. Keeping in view that toll collection would not be an option in rural areas, an annuity based scheme is being considered to lure private developers. In the annuity based scheme, the government would pay the developer on a yearly basis after the completion of the project.

8.3.4 Urban Transport

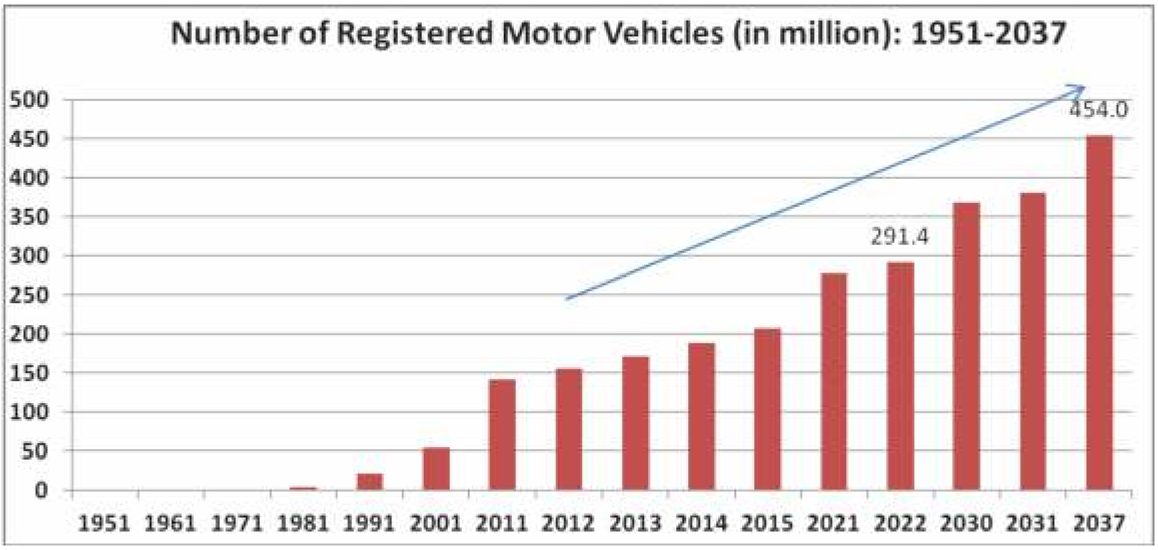
New initiatives like Bus Rapid Transit (BRT) systems and air conditioned buses have been taken by the various state governments to improve the road based public transport systems in cities. Bus Rapid Transit systems already exist in Pune, Delhi, Ahmedabad, Mumbai and Jaipur with new ones coming up in Kolkata Hyderabad Lucknow and Bangalore. High Capacity buses can be found in cities like Mumbai, Bengaluru, Nagpur and Chennai. In addition, many state transport corporations have introduced various types of services like low-floor buses for the disabled and air-conditioned buses to attract private car owners to help decongest roads.

Modern rapid transit systems are running successfully in Kolkata, Delhi and Bangalore, and construction of mass rapid transit (MRT) is in progress in seven more cities. In addition, Monorail and Light rail systems have been considered for 15 other cities, of which two of them are under construction and trial. The Government is providing budgetary support to the States through its programme called JNNRUM to improve the urban transport infrastructures and services.

8.4 TRANSPORT DEMAND

The growth of vehicular traffic on roads has been far greater than the growth in the road network; as a result the main arteries face capacity saturation. India has experienced tremendous increase in the total number of registered motor vehicles from about 0.3 million in 1951 to about 142 million in 2011.

The registered motor vehicles in the country grew at a CAGR of 9.9% between 2001 and 2011. If the growth is assumed to be same upto 2015, and then to have moderate rate of 5% and 3% during the subsequent periods upto 2022 and 2037 respectively, the estimated registered motor vehicles fleet will be about 454 million by the year 2037, as shown in Figure 1.



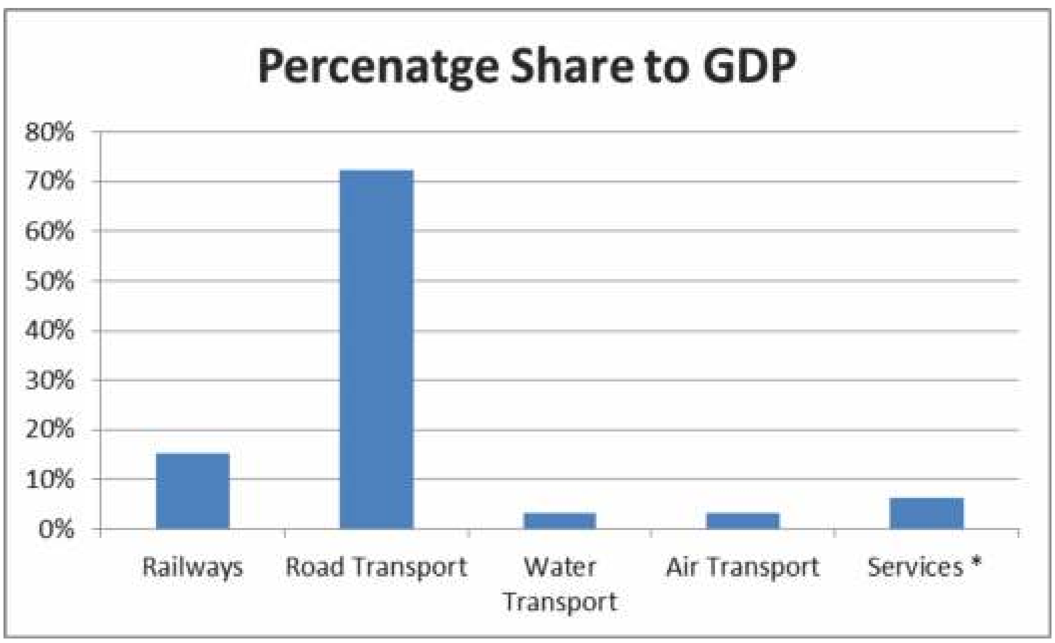
Source: Transport Research Wing, Ministry Of Road Transport & Highways, GoI & Projected

Figure 1: Number of Registered Motor Vehicles (in million) with Projection

8.5 OTHER RELATED ISSUES

8.5.1 Modal Share in GDP

Transport sector accounts for a share of 6.4% in India's Gross Domestic Product (GDP). The contribution of various sub-sectors to GDP is given in Figure 2, where it can be seen that the maximum share is of road transport.



* Services incidental to transport

Figure 2: Share of Transport Sub-Sectors in GDP

8.5.2 Road Safety

The rate of accidents and fatalities is a major concern on the road network in India. The rate of accidents and fatalities are steadily increasing by each passing year, with 142,485 road fatalities recorded in 2011. India leads the world in absolute number of road deaths per year.

Though National Highways constitute only 2% of the road network, majority of road fatalities occur on National Highways followed by State Highways. In addition, a significant share of road accidents and fatalities occur on urban roads, and vulnerable road users have the maximum risk of exposure in urban roads due to limited or negligible road support infrastructure like footpaths, pedestrian crossings, cycle tracks and parking spaces.

8.5.3 Environment

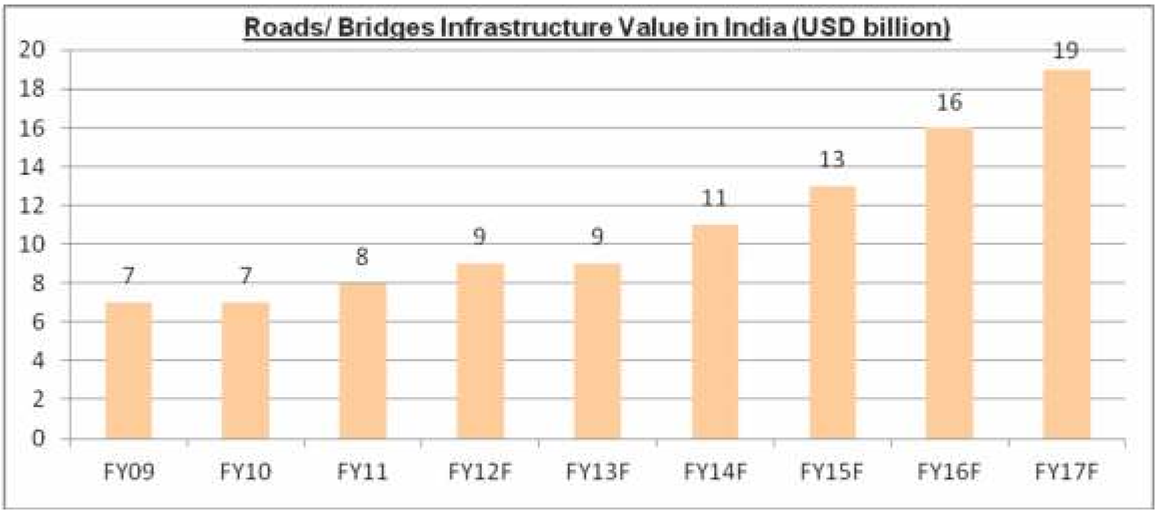
Road transport has an adverse impact on environment. The problem is acute in cities where motor vehicles generate noise and fumes and create significant air and noise pollution causing serious harmful impacts on the health of residents.

Road construction also contributes to significant deterioration of environment by emission of dust during construction and by use of non-renewable materials.

8.5.4 Investment in Road Sector

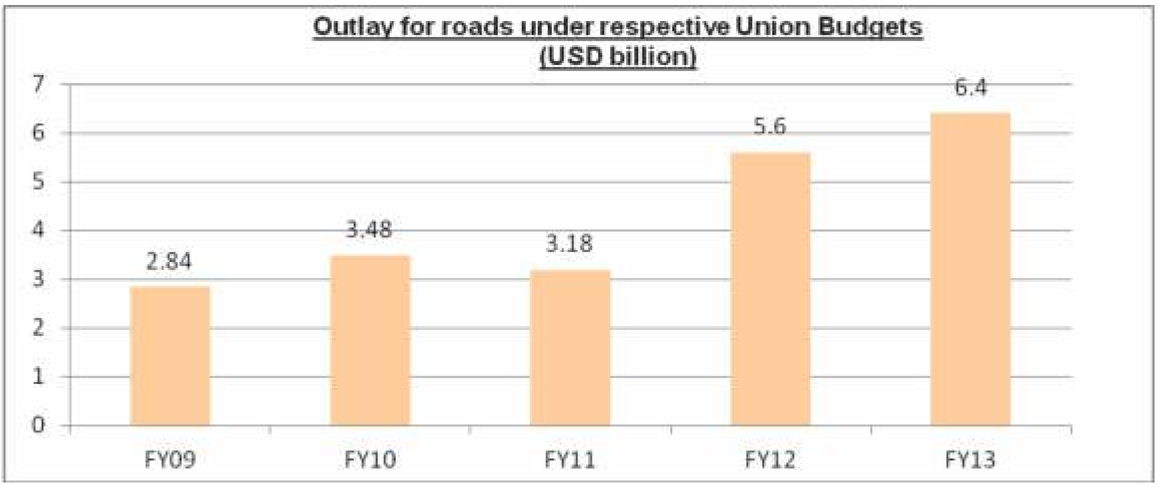
Future national and state highway projects are estimated to create an opportunity of investments in the order of USD 51 billion over next five years. It is worth noting that road projects contribute around 60% of PPP projects in the country. To promote the sector further, the government has allowed 100%t FDI under the automatic route for all road development projects, and 100% income tax exemption is granted for a period of 10 years. Foreign contractors were awarded projects worth about USD 1.69 billion during the period 1999-2011, and the contractors from Malaysia and Russia had topped the list of foreign contractors. About 55 per cent of all such contracts were funded through BOT, BOT-Annuity and BOT-SPV routes.

The value of total network of roads and bridges infrastructure in India is expected to grow at a CAGR of 17.4% over the five year period 2012-2017 (i.e. 12th Plan) to reach a value of USD 19 billion as shown in Figure 3. The roads have been a key focus area of budget allocations over the years. The budget outlay for Road Transport & Highways had a robust growth of 23 per cent CAGR from 2009 to 2013. Budget of 2013 witnessed a 25 per cent rise in budgeted capital expenditure for national highways to USD 1.6 billion. In the budget of 2013, the government has planned to construct/rehabilitate 130 bridges and 7 bypasses. The annual outlay for the roads under Union budgets for the period 2009 to 2013 is shown in Figure 4, which showed consistent increase. Considering the growth and projections for the budgetary outlay for development of roads to be similar in the intervening periods till 2022 and 2037, the budgetary allocations required shall be 11 billion and 17 billion USD respectively, in the year 2022 and 2037.



Source: Business Monitor International (BMI), Aranca Research (F - stands for forecast)

Figure 3 : Roads/Bridges Infrastructure Value in India (USD billion)



Source: Respective Union Budgets, Aranca Research

Figure 4 : Outlay for Roads under Respective Union Budgets (USD billion)

8.6 PROSPECTIVE TRENDS IN TECHNOLOGY DEVELOPMENT

The massive growth in transportation infrastructure has to be dependent upon the availability of petroleum crude based fuel, stone aggregates and bitumen and also to be concerned about issues relating to environment, road safety and land availability. Additionally the road infrastructure of future will have to be reliable – Optimising the availability of infrastructure (life time engineering, fast hindrance free maintenance, balancing demand and capacity, asset management tools), Green – environment friendly (reducing carbon footprint, saving natural resources, emission control, sustainable), safe and smart (design, smart communication and monitoring, multi-functional) and human friendly (accessible, catering to ageing drivers, children, etc). These four construction concepts form the frame work of thinking about technical solutions and research programmes.

Roads will continue to carry by far the majority of land freight transport and passenger traffic. Keeping this traffic rolling is the main concern of the authorities. Building new roads or expanding the pavement lanes might seem to be obvious way to do this. However, the demand for traffic space will always exceed the supply. Congestion free road transport continues to be an issue, traffic jams are a fact of life. Above all, the concern extends to conserving the existing network and upgrading the existing the structures to provide quality standards of the future; reliable and available around the clock at socially acceptable costs.

The main question at this stage would be 'How to meet this future', i.e., what developments are necessary to reach the future step by step. Lessons from the past have shown that radical breakthroughs in technology will not occur from one day to another, but are an accumulation of small stepping stones.

The transport corridors, whilst road based, will increasingly become integrated multi-modally for passenger transport, and provide logistic connections for freight, including routine scheduling and enabling real-time decisions in both passenger and freight movement. Some of the advances which can be expected across different modes of transportation are:

a) Electronic means of access (tele-working, telecommuting, e-commerce, etc) to grow and to complement travel, but to provide only partial substitution, reduction in demand for some kinds of transportation by replacing physical movement with 'virtual' movement of people and goods where appropriate

b) Public transport services and freight logistics to be highly optimised and real time responsive. Improvement in operational management by creating new inter-institutional arrangements – both formal and virtual–often crossing public and private lines to overcome current jurisdictional and sectoral fragmentation

c) Development of efficient and effective means for selecting and completing infrastructure projects, especially information infrastructure, that add to transportation system capacity without causing an impact on other important areas of life (land use, environment, computing and comparing carbon footprint for various alternatives, etc.)

d) Rationalisation of system design and operations at a level above the individual modes, to improve the flow of people and goods at intermodal transfer points (sea to rail, land to air, etc.)

e) Improvement of the availability of transportation services by increasing the coverage of feeder connections and by expanding from a hub-and-spoke system to a distributed network for national, regional, and line-haul services

f) In the urban areas, omnipresent vehicles dominate the configuration of public spaces in towns and cities. By car, everything is within the reach. The huge rise in number of vehicles and car use is now a scourge of city life. The time has come for a revolutionary change in the configuration of public spaces in order to facilitate and reduce the impact of road transport on people's health and lifestyles. Special attention and care must be paid to most vulnerable users of roads and public spaces – pedestrians, cyclists, people with disabilities, old people and children. The best place for the more vulnerable category of users is the ground level in the open air. Citizens want their streets back to upgrade their social activities in their living surroundings. They are tired of their living space being invaded by polluting cars and trucks speeding by. On the other hand, they expect facilities and services to meet their daily needs. All these needs are to be satisfied by one and the same public space. Designing a configuration for public space that allows multi-functional use of the available area at different times of the day could be an option.

8.7 PROJECTED SCENARIO

It is expected that Transport and Logistics will undergo significant changes in the coming decades owing to various policies adopted by the government.

8.7.1 Some Salient Expectations

According to McKinsey Report (McKinsey &Company, 'Building India, Accelerating Infrastructure Projects', August 2009),

- GDP in 2030 will be five times of GDP in 2010.
- 590 million people will live in cities - nearly twice the population of United States today.
- 70 cities will have population of 1 million plus - up from 53 in 2011; Europe has 35 today
- $1.2 trillion capital investment is necessary to meet projected demand in Indian cities;
- 700-900 million square meters of commercial and residential space needs to be built, or a new Chicago every year.
- 2.5 billion square meters of roads will have to be paved - 20 times the capacity added in past decade.
- 7400 kilometers of metros and subways will need to be constructed – 20 times the capacity added in past decade

By 2037, FDI in multi brand retailing will be common and almost all the States will have multi-national supermarkets operating in retail sector. This will bring in a revolution in transport and logistics, and push the governments to build the road infrastructure to suit this requirement with new technologies in transport and logistics.

8.7.2 Lifestyle

Changing lifestyles are contributing to the increasing demand for travel. In particular:

- Higher disposable incomes are generating demand for more leisure and holiday travel.
- People are generally spending more time on leisure activities assisted by flexible working patterns.
- Increased opportunities for economic activity beyond retirement age will increase demand for mobility among the elderly.
- Tourism is continuing to grow, with faster long distance travel.
- Travel in non-peak hours may increase, at a greater rate relative to commuting travel, as a result of increased leisure time.
- National and international travel will become increasingly common.

- The traffic congestion is spreading spatially, outwards from the major conurbations, and temporally to outside peak periods, leading to more extensive periods of regular congestion within the day.

8.7.3 Traffic Growth and Future Demand

Growth of passenger and freight demand up to 2030, given by Working Group on Roads for the National Transport Development Policy Committee, GoI, is shown in Table 2. It has been further projected for up to year 2037. The business as usual (BAU) scenario shows that projected freight traffic by 2030 will be of the order of 2,202 BTKM and by 2037 it is estimated to be 2,442 BTKM. Passenger traffic will be 78,409 BPKM by 2030 and it is estimated to be 99,965 by 2037. Same has been shown for BAU graphically in Figure 5. The other scenarios shown in Table 2 are based on elasticity of road freight and passenger traffic with respect to Gross Domestic Product (GDP), in conjunction with three variants of growth rates which have been assumed.

Table 2 : Projected Road Freight and Passenger Traffic

Year	BAU		Scenario I		Scenario II		Scenario III	
	BTKM	BPKM	BTKM	BPKM	BTKM	BPKM	BTKM	BPKM
2011-12	869	8,811	1,066	10,963	1,066	10,963	1,089	11,508
2016-17	1,125	16,171	1,828	25,134	1,779	24,139	1,868	26,383
2021-22	1,457	29,679	3,053	55,341	2,972	53,150	3,205	60,485
2026-27	1,886	54,468	4,961	116,989	4,962	117,028	5,498	138,669
2029-30	2,202	78,409	6,532	178,856	6,750	187,914	7,601	228,127
2030-33	2,319	88,533	7,159	206,042	7,479	220,047	8,468	269,304
2035-37	2,442	99,965	7,847	237,361	8,287	257,675	9,433	317,913

Notes : In Business As Usual (BAU), the freight traffic is assumed to grow at 5.3% per annum, and the passenger traffic to grow at 13% per annum.

BTKM – Billion Tonne Kilometre; BPKM – Billion Passenger Kilometre

Scenario I: Staggered GDP growth over the horizon

Scenario II: GDP growth of 9%

Scenario III: GDP growth of 9.5%

Source : Working Group on Roads for the National Transport Development Policy Committee, GoI.

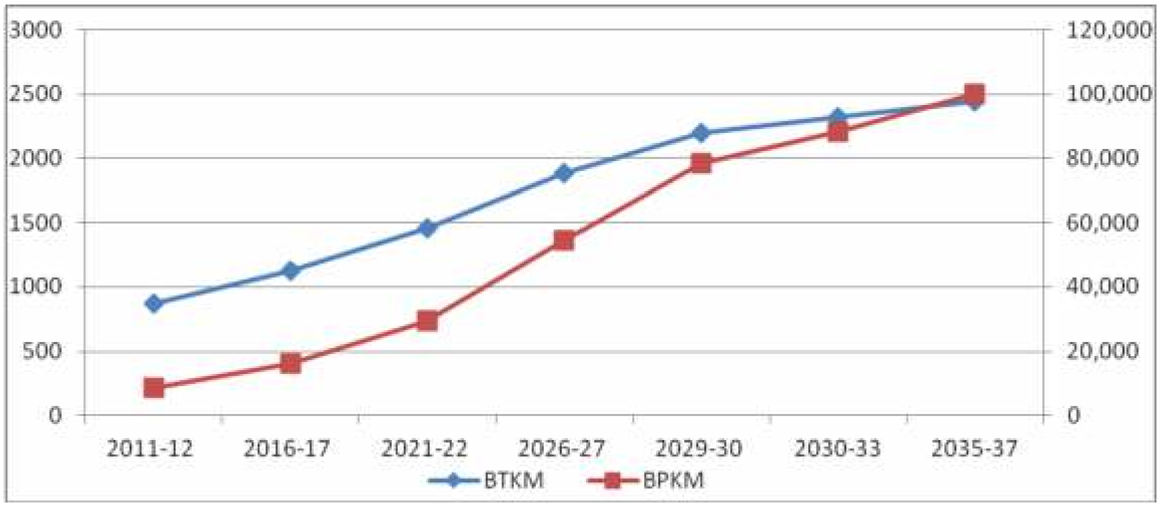


Figure 5 : Projected Road Freight and Passenger Traffic (BAU Scenario)

8.7.4 The Implications

In India, road network is generally considered as an infrastructure comprising of roads, junctions and the structures. But, it is clear through the development vision for roads, that by 2037 there are likely to be three pillars of the road-based infrastructure:

- the smart roads
- the communication and control systems that links roads, vehicles and drivers (road users)
- the financial systems that pay for the roads, communications, infrastructure and other services seamlessly

The major difference will be that across the country, government's role will be changed to facilitator and private sector (contractors and consultants) will be the implementation agencies for design, construction, operation and maintenance of all types of major roads and highways.

The majority of road users will be tech-savvy and the pressure of the techno-savvy road users will drive the implementing agencies/ roads authorities to adopt the following themes in road travel:

SMART Travel : The transport system should provide user information 24x7 and it should be managed responsively and efficiently, making full use of available technology.

SAFE Travel : The infrastructure and its operations shall be inherently safe. They should provide as much protection as possible against driver error.

CLEAN Travel : There should be no net damage to the environment; health impairing pollutants should be eliminated or minimized.

RELIABLE Travel : The travel on the network shall be reliable, and any disruptions that occur will be predicted in advance and measures taken to mitigate their effect on road users.

SUITABLE to the Road Function : The capacity, safety and level of service of the components of the road infrastructure should be proportional to need and function. The form and acceptance of roads should complement their respective functions and should be environmentally acceptable.

8.7.4.1 *The Road Network*

Every business and commercial enterprise in the country will be using the road as the means for the business advantage, and therefore, the road itself will be developed as a business entity with necessary charging for its usage. While there will be variation of charges for spatial and temporal usage of the network, technology will facilitate seamless road travel through interoperable operations of the multiple networks by integrated common banking.

Expressways – By 2037, India will have fully access controlled six lane Expressways connecting four major metropolitan cities, and all state capitals in the country and major industrial areas will be to the expressway network.

- The expressways will have world class amenities to cater for different requirements for long distance travelers, such as rest areas, safe entry and exits, variable message signs to inform the driver of various road features ahead, and all safety related infrastructure facilities to accommodate any driver error.
- The expressways will increasingly become integrated multi-modal facility for passenger transport, and provide advanced logistics for freight movements, including routine scheduling and enabling real-time information on both freight and passenger movements.
- The major share of India's freight will be transported through expressways.

8.7.4.2 *National Highways*

- National Highways will be 4 or 6 lane semi-access controlled highways having dedicated bus lanes and segregated facilities for cyclists, two wheelers and pedestrians.
- The national highways will have safety features for all types of road users and will be linked to expressways, and will also be equipped with real time information system.

Urban Roads

- The urban network will have traffic control systems that dynamically adjust traffic lights according to real-time traffic flows.
- Speed regulation and routing by means of variable message signs, which will be common to ensure a more informed and stable traffic flow.
- The traffic on roads in major towns and cities will be managed through an integrated traffic management system, where traffic signals at all junctions will be controlled through a centralised traffic management centre to manage the congestion and safety of all road users.
- The towns and cities will have dedicated bus lanes, segregated facilities for pedestrians and cyclists, pedestrian only areas and designated on- and off-street parking arrangements through electronic metering system.
- The public transport will be controlled through real time information display on bus stops and drivers will be communicated through GPS enabled systems to avoid congestion.
- The cities will witness innovative traffic and demand management arrangements like contraflow, one-way streets during peak hours, congestion pricing, bus priority, area traffic control or coordinated signalling system, etc.

- The enforcement of road transport will be technology based through surveillance camera/sensors.
- All medium to large cities will have park and ride schemes, where cars can be parked on large designated off-street car parks on the peripheries of the city, and public transport made available from these interchanges to different places of work in the city.

Rural roads

- All villages in the country will be connected by at least a single lane all-weather paved road to the nearest district roads.
- The rural roads will have suitable safety provisions for pedestrians, cyclists and other NMT modes, as well as roadside amenities.

8.7.4.3 *Road Construction and Maintenance*

- Roads with longer life will be constructed based on principles of life cycle cost, to keep disruptions for upgradation and maintenance to a minimum.
- All roads in the country will be constructed using mechanised means, and by this time, standards for all types of roads and a robust QA/ QC mechanism would have been developed and practiced extensively.
- New contracting arrangements will be implemented to enable quality oriented and dispute free construction like New Engineering Contract (NEC).
- Incident clearance will be much quicker, aided by high speed data gathering equipment to record the scene and to provide legal evidence where it is required.
- By 2037, all States will have a robust Road and Bridge Asset Management Systems in place, and all decisions regarding maintenance will be data led and based on principles of life cycle cost.
- The Expressway and National Highway networks will be managed (maintenance) by joint venture teams of consultants and contractors in partnership with the road authorities through performance based long term maintenance contracts.
- SHs and other roads will be managed through a similar arrangement (JV of Contractors & Consultants) in partnership with the road authorities.
- Monitoring of road condition will be achieved by the use of condition monitoring vehicles traveling at traffic speed, and through implanted sensors in road pavements and structures, so that they register and record condition automatically.

8.7.4.4 *Communication Infrastructure*

IT applications have not been substantially tapped for road sector so far, but it is going to revolutionize the road sector in future. The communication infrastructure is going to be embedded to the road transport system that will have a profound impact in the way the road transport will be used in coming decades. Intelligence built into the road and vehicle to assist the road user, will be common in major part of the road network.

Roads

- All Expressways and National Highways will be connected to National Road Telecommunications System similar to the one adopted in the motorways in the UK, where real time travel information is processed through optical fibre cables and sensors laid on the road, to centralised traffic management centres, to inform the road users about the condition on the road network at any given time of the day to enable improved travel plan.
- The record of axle loads will be collected through a similar system (sebsorson roads) and wired to the agency responsible for axle load regulation and management to monitor overloading on roads.
- The Expressway and National Highways will be designed for uniform operating speeds across the country and speeds on these road networks will be monitored through a network of sensors and speed cameras installed at strategic locations.
- The 'user pays' system will be adopted on Expressways and National Highways network and the toll collection system will be completely automated and interoperable to achieve unhindered travel of freight and passengers.
- The travel time between the major nodal centres will be reduced to more than half of what exists today.

Vehicles

- The developments in vehicle to vehicle communication will enable the development of collision avoidance systems, and for minimizing the effect of impact on the occupants in case of a collision.
- Vehicles will be loaded with active and passive safety systems to prevent occurrence of accidents by making up for the driver skill deficiencies and saving occupants from any injury in the event of an accident
- Driver impairment interlocks (for alcohol, fatigue etc) will limit or prevent vehicle movement when risk is too high
- Users will draw on multi-modal journey management systems, with the aim to minimize road travel.

8.7.4.5 *Financing of Roads*

- The construction and maintenance of Expressways and National Highways will be completely carried out in PPP mode or in some sort of hybrid arrangements with the government.
- Dedicated Road Funds will be in place in all States to construct and maintain roads managed by the States.
- Other possible sources of funding in 2037 might be:
- Payment for information before and during journeys
- Payment for road space/usage and congestion charging in major cities
- Technology will develop to charge all motorized road users for their use of roads by kilometers driven, according to time and place through automated DSRC system

- Growth of public/ private hybrid funding, including shadow tolling and 'pay at the point of use'.
- Electronic cash flow principles will become well established in transport, both for priced road use and multi modal transactions with through ticketing, etc.
- Pricing of road use will be established in major cities

8.7.4.6 *Environmental Imperatives*

The vast network of roads will take advantage of novel concepts for arresting environmental degradation due to increasing demands of infrastructural projects through adoption of various possible safeguards that can be designed for environment and ecology.

- Road drainage system to be used uniformly for rain water harvesting
- Use of recycled /waste materials in all highway construction to be mandatory
- Road network to be harnessing solar and wind energy throughout the country

8.8 VISION FOR INAE

The activities of the Academy will be expected to lead to the preparation of policy directives on various aspects of Engineering inputs required to enable the Country to achieve the scenario envisaged in Section 3.4 of this write up, in terms of concepts, the road network system, management of the network, financing, communication infrastructure, environmental imperatives, materials required, construction technologies. In order to evolve related policy documents, which can be considered suitable for implementation, the INAE will need to interface its efforts with the different stakeholders such as R&D institutions, the construction industry, the Governmental agencies dealing with finance & planning of infrastructure for the country and human resource development. A multi-disciplinary INAE Forum on Infrastructure will help in pursuing this vitally important subject area with intensity and due continuity. The INAE should also take up research studies on Materials and related Technological aspects for Road network development, which run across different disciplines of Engineering.

SS9 : RAILWAYS

9.1 PREAMBLE

Transport is a derived demand and its growth depends on several factors which, inter alia, include financial, social and environmental considerations. Forecasting transport demand therefore is a difficult area and many such estimates in the past have differed widely from the projected targets. The situation in the recent decades has further changed as the environmental considerations and availability of resources are proving to be a major bottleneck in the developmental process both for the Transport sector as well as for sectors which are responsible for generating transport demand.

Currently more than 90% of the inter-regional traffic is carried by Rail and Road. The Rail, in spite of being environment friendly, is loosing its market share. The share of Rail in Freight Traffic has come down from 89% to 30% since 1950-51 and for the Passenger Traffic, it has reduced from 69% to 15%. Currently, there are efforts through policy directives and otherwise to improve the share of environment friendly Rail mode. To give an example, the 12th Plan (2012-2017) envisages a two percent improvement in Railway market share.

The INAE's "Technology Foresight and Management Forum for addressing National Challenges" besides several other areas is also involved in a Technology Foresight Exercise to make the 'Transport Green'. Here, besides other initiatives the primary effort is to improve the 'modal share' of environment friendly Rail mode. Such efforts are very likely to enhance the growth of Rail traffic.

It will thus be appreciated that forecasting Rail traffic is not an easy task as it is related to several other variables. However, a broad assessment has been made by studying the past, current, and likely future situations. An attempt has been made to project the traffic for the year 2037. The summarized position can be seen in Table-1 wherein the assumed Compounded Annual Growth Rates (CAGR) have also been given.

Table-1 : Railways – Freight and Passenger Traffic Projections

A.	Freight Traffic	2012-13	2037-38	CAGR
	Originating Freight Traffic in Million Tonnes	1,007	3,250	5%
	Net Ton-Km in Million	644,601	2,000,000	
	Average Lead in Km	640	616	Reducing @ 1 Km/Year
B.	**Passenger Traffic**			
(a) ·	Suburban Passengers in Million	4,541	11,640	4%
·	Suburban Passenger-Km in Million	149,460	487,729	
·	Suburban Passenger Lead in Km	33	42	1%

(b)	·	Non-Suburban Passengers in Million	4,099	20,792	7%
	·	Non-Suburban Passenger-Km in Million	967,442	7,858,879	
	·	Non-Suburban Passengers – Lead in Km	236	378	2%
(c)	·	Total Passengers in Million	8,640	32,432	
	·	Total Passenger -Km in Million	1,116,902	8,346,607	
	·	Total Passengers – Lead in Km	129	257	

Note : For 2022-23 suitable interpolation can be done.

9.2 FREIGHT TRAFFIC – THE PRESENT AND THE FUTURE PROJECTIONS *

9.2.1 Projection of Originating Tonnes - Based on Assumed Growth Rates

Projections have been made in Fig.1 on the basis of assumed annual growth rates of 4%, 5%, 6% and 7%. These are depicted in the graph given below. The base year is 2012-13 when 1007 million tonnes of freight was transported. At 4% CAGR rate originating freight traffic in 2037 will be about 2.6 billion tonnes. At the upper end assuming a growth of 7% per annum the originating traffic would be 5.1 billion tonnes.

Figures in Millions Tonnes

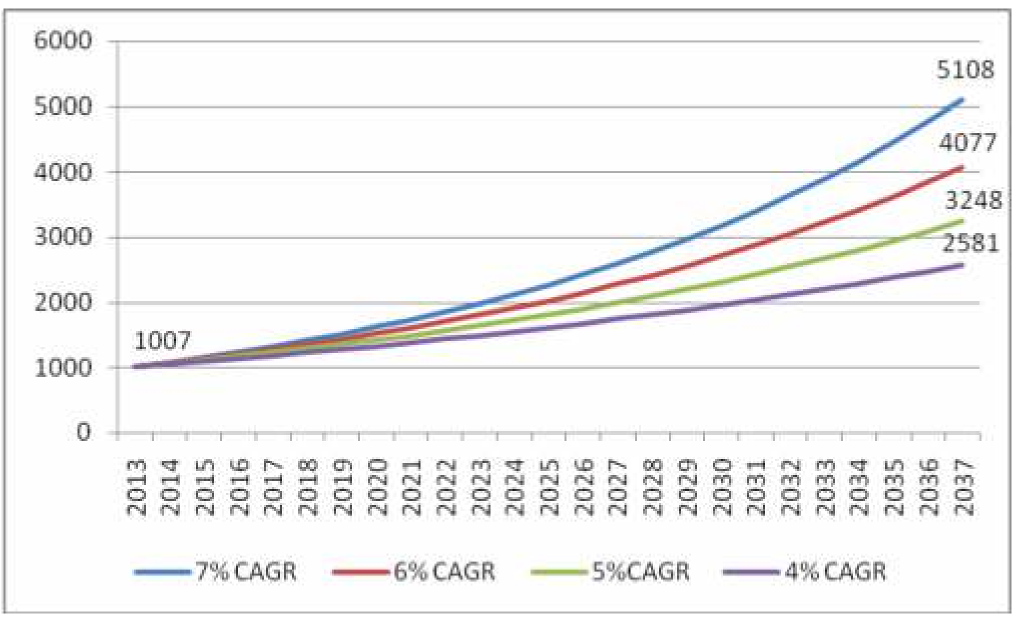


Fig.1: Originating Freight Traffic projection at different Growth Rates for 2037.

It may be more appropriate to consider a modest growth rate of 4% to 5% because (i) recent trend has shown a modest growth rate, (ii) there are severe capacity constraints on the system and the rate of creating additional capacity is at present very slow, (iii) focus and investment continues to be on socially desirable projects which do not create capacity where it is most required and changing to a more demand driven investment plan will take some time (iv) funding needs for creation of additional capacity are likely to be extremely high and will take time to generate as historical systems for funding Rail projects will have to change and (v) as Railway projects have long gestation periods it may be a decade before things begin to gather pace. Although the economy, if growth picks up, may demand a higher growth rate closer to 7%. The GDP growth rate which is projected at 7%-8% is also uncertain in view of various factors.

***Projections based on recent trend in growth.**

9.2.2 Projection of Net Tonne Kilometers

Figure. 2 indicates projection of Net Tonne Kilometers. This is based on the assumption that Average Lead will progressively decline from a level of 640 Km at present by 1 km per year to 616 Km per year in 2037. This is in view of changing patterns in industrial development and agricultural production which is getting more dispersed. New Port developments on East & West Coasts also affect lead. The present (2012-13) figure is estimated at 644,601 Million NTKMs (Rail Budget 2013 Documents). NTKMs have been compiled by multiplying originating Tonnes in Fig.1 by the average lead.

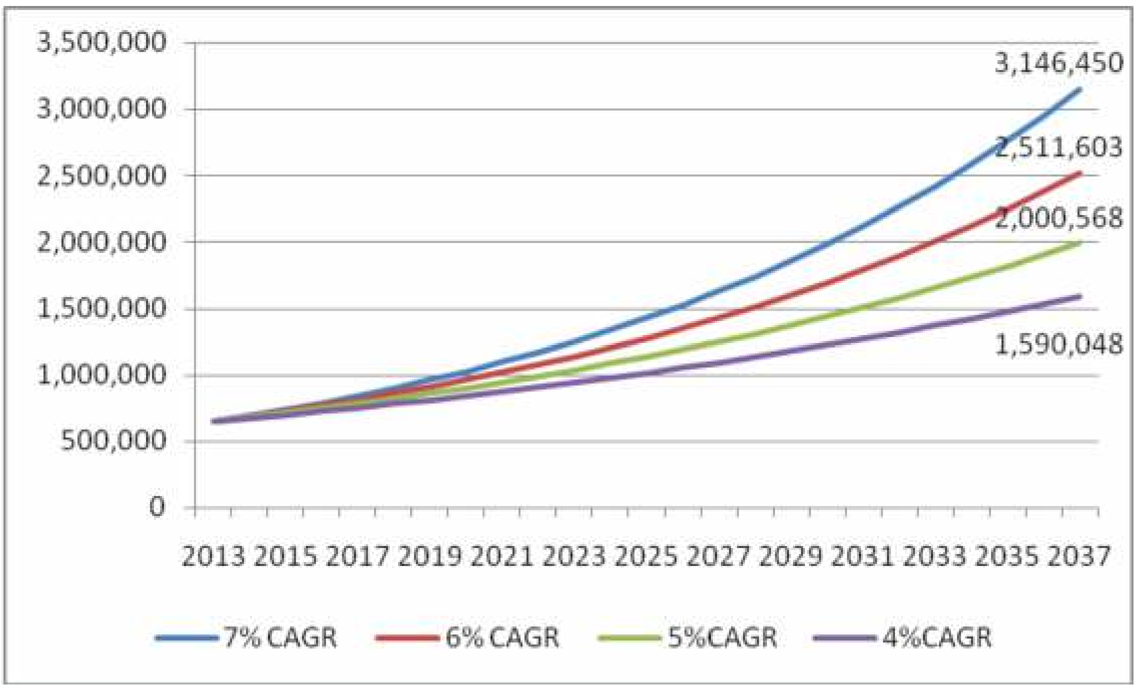


Fig.2: Growth in NTKMs assuming originating loading as indicated in Fig. 1 and declining lead from 640 Km to 616 Km. Figures in Millions

9.2.3 Projections of a World Bank Expert

A rough estimation of Freight Net Tonne Kilometres was made in an expert study (Louis Thompson which he published in a Paper 'A Vision for Railways 2050' for International Transport Forum in 2010 (OECD). In this study, it is projected that in 2035 NTKMs will be 858,794 Million and in 2050, 1,524,481 Million. This was indexed on data for the year 2000 when NTKMs were 305,201 Million. It has been projected that a five-fold growth will occur in fifty years upto 2050. However, the projections went haywire in the first eight years of the decade itself in view of very high GDP growth owing to which the projections were surpassed until the slowdown of 2008. Clearly the three-fold growth predicted between 2000 and 2037 will be surpassed.

9.2.4 International Transport Forum Assessment for Non OECD Countries

The International Transport Forum monitors global trends and makes projections for 2050 for Passenger & Freight traffic broadly for OECD and Non OECD countries. Non OECD countries are the developing nations like China, India and others. In their Transport Outlook for 2012 they have indicated the growth pattern for NTKMs up the year 2050. This projection in High GDP growth scenarios, which is appropriate for India, estimates a growth factor of 3.25 times for the year 2037 *vis-a-vis* the 2010 level (see Fig.3). In 2009-2010 freight traffic generated was 600,548 Million NTKMs. Based on this the freight traffic volume in 2037 would be 1,951,871 Million NTKMs which broadly conforms to the 5% growth rate level projected in Fig.2. This assumes that overall market share of Rail in freight transport remains the same. The ITF also predicts a decline in rail share.

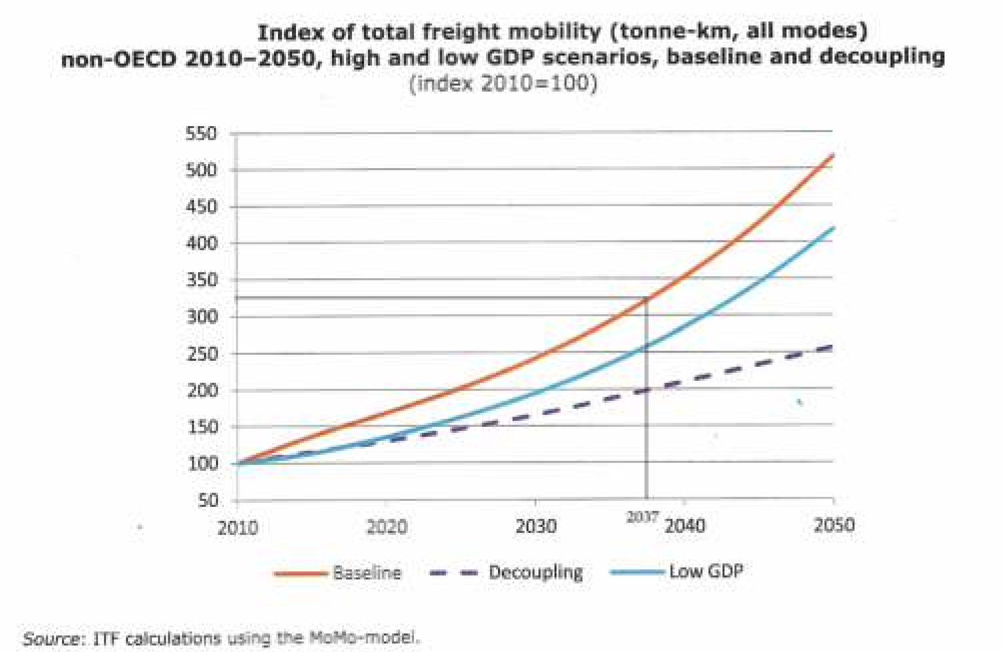


Fig.3: Index of totat freight mobility (tonne-Km, all modes)
Non-OECD 2010-2050, high and low GDP scenarios, baseline and decoupling

9.2.5 Shorter Term Projections

1. *12th Five Year Plan:* The Projection made by the Planning Commission for 12th Five Year Plan for the year 2016-17 is at originating freight tonnage of 1,405 Million Tonnes at a CAGR of 7.8%, Net Tonne kilometres at 927 Billion NTKM at a CAGR of 7.7% and lead of 660 Km which is expected to decline from 665 Km in 2012-13. IR is expected to fall short of this target. We are already in the second year of the Plan and have not achieved the first year's (2012-13) target of 1038 Million tonnes and the second year's (2013-14) target of 1,119 MT is also much higher than the target mentioned in the Annual Budget.

2. *Vision 2020 Document of Indian Railways:* The forecast given for the year 2019-20 was originated from the loading of 2165 Million Tonnes and net Tonne kilometres of 1407 Billion NTKMs with a growth rate of 10% over a decade. The Report stated that “Indian Railways shall pursue an aggressive customer-centric and market focussed high growth strategy...” The targets were clearly overstated and unrealistic and will not be achieved.

9.2.6 Discussions in Railway Board

Informal discussions in Railway Board revealed that a realistic target for annual incremental originating tonnage would be in the range of 50 to 75 million tonnes. Applying this methodology gives an originating traffic in 2037 of between 2.21 Billion Tonnes and 2.68 Billion Tonnes which again gives us a figure of about 4% annual growth. If IR achieves an incremental loading of 75 million tonnes on average it would translate into NTKMs 1,730 Billion NTKM which again conforms to the assessment of 4% to 5 % growth.

9.2.7 Conclusion

Based on the above discussion for the Year for planning purposes we may consider the following Freight Traffic levels for 2037:

ORIGINATING FREIGHT:	3250 Million Tonnes	(Growth Rate 5%)
NET TONNE KILOMETRES:	2000 Billion NTKMs	
AVERAGE LEAD:	616 KMs	

The corresponding Traffic figures for the Year 2012-13 are as under:

ORIGINATING FREIGHT :	1007 Million Tonnes
NET TONNE KILOMETRES :	644 Billion NTKMs
AVERAGE LEAD :	640 KMs

9.3 PASSENGER TRAFFIC – THE PRESENT AND THE FUTURE PROJECTIONS *

9.3.1 Present Passenger Volumes on IR

Indian Railways is the largest Passenger Transportation Railway system in the World. In 2012-13 the network carried 8.64 Billion passengers and generated 1,117 Billion Passenger Kilometres. Railway Passenger Traffic may be divided in two main categories i.e. Suburban which caters to suburban travel in the cities of Mumbai, Kolkata and Chennai and Non Suburban Traffic which includes intercity, regional and long distance services. In 2012-13 it is estimated there were 4.54 million suburban and 4.1 million non suburban passengers that travelled on the Railway. Suburban Passengers accounted for 149.46 Billion Pass. Kms. and Non Suburban 967.44 Billion Pass. Kms. The average length of a suburban journey is 33 Km while that of a Non Suburban trip is 236 Km. Over the last five years whereas number of originating passengers have grown at an average rate of 5.78%, the passenger kilometres have grown at 7.73%. The growth rate is higher in case of Non Suburban at 7.66% in Passenger numbers and 8.55% in Passenger Kilometres while Suburban growth has been 4.26% in Passenger numbers and 4.58% in Passenger Kilometres. The growth rate in average length of journey has been 0.26% in Suburban and 0.58% in case of Non Suburban journeys. It needs to be noted that growth has been high because of exceptionally low fares and no increase in fares over several years.

Table 2 : Growth in Passenger Traffic on Indian Railways

(Figs. in Millions)

Year	No. of Passengers			Passenger Kilometers		
	SUBURBAN	NON SUB.	TOTAL	SUBURBAN	NON SUB.	TOTAL
2007-08	3,689	2,835	6,524	1,19,842	6,50,114	7,69,956
2008-09	3,802	3,118	6,920	1,24,836	7,13,196	8,38,032
2009-10	3,876	3,370	7,246	1,30,197	7,72,548	9,02,745
2010-11	4,061	3,590	7,651	1,37,127	8,41,381	9,78,508
2011-12	4,337	3,846	8,183	1,44,057	9,02,465	10,46,522
2012-13	4,541	4,099	8,640	1,49,460	9,67,442	11,16,902

**Source Indian Railway Year Book for Relevant Years*

9.3.2 Assumptions & Projections for Future Growth

The present policy of keeping passenger fares artificially low and suffering a loss on passenger services of about Rs. 24,000 Crores is unsustainable in the long run. By running the passenger business below cost a heavy burden is placed on the freight business in view of the huge internal cross subsidy that is necessary to ensure the organisation as a whole is able to sustain itself. High freight tariffs will also result in that business segment becoming uncompetitive. It is therefore assumed that rational pricing policies will be pursued in future. Even modest increases in passenger fares will help curtailing growth rates. With a buoyant economy, rapidly growing middle class population and massive urbanization expected in the next few decades the pressure on the rail system will be severe in view of capacity constraints in terms of line capacity, inadequate terminal capacity and non-availability of coaches. The Railways will carry only a minor share of overall passenger mobility with private vehicles and bus transport likely to grow more rapidly. Once the Dedicated Freight Corridors are operational the situation should somewhat ease. Suburban trips (Numbers) which have been growing at 4.58% are assumed to grow at a 4% CAGR in the long run and Non Suburban travel is assumed to grow by 6% to 8%. Average lead in case of suburban travel is assumed to grow at 1% CAGR and in case of Non Suburban travel by 2% CAGR. These assumptions translate into the growth indicated in the Fig. 4 and Fig. 5

(Figs. in Millions)

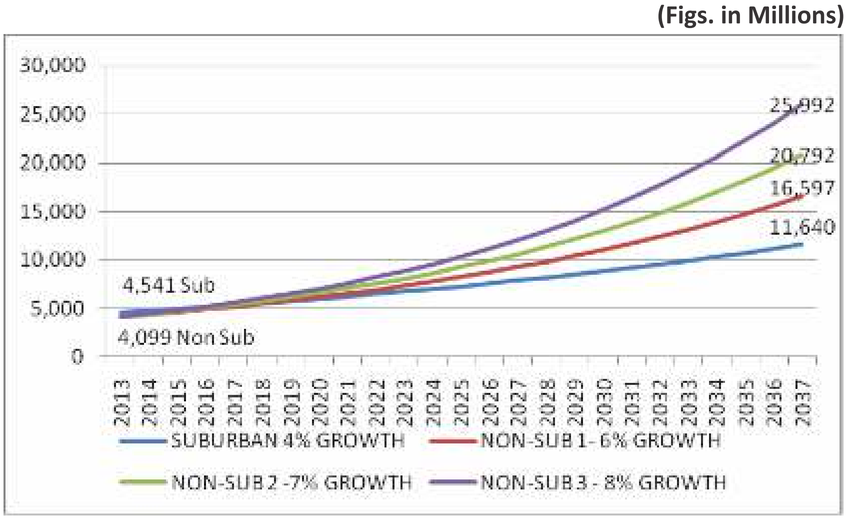


Fig. 4 : Projected Growth in Passenger Numbers – 3 Scenarios for Non Suburban Growth

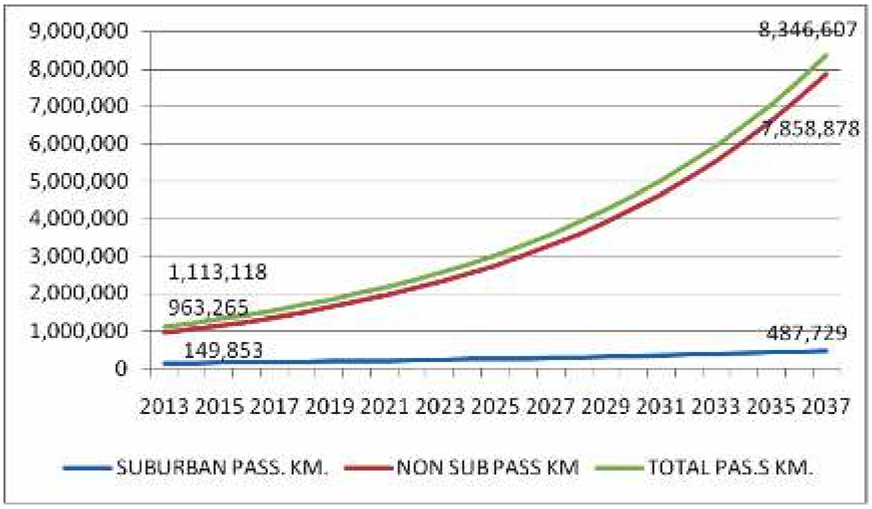


Fig. 5 : Projected Growth in Passenger Kilometres assuming 7% CAGR in Non Suburban Passenger Numbers and 4% in Suburban Passenger Numbers

What the figures indicate is that there is likelihood of a 5 fold increase in Non-Suburban numbers and 2.5 fold increases in Suburban Passenger numbers. At the same time Passenger Kilometres will grow 7 times in case of Non Suburban traffic 3.25 times in Suburban traffic. In view of the high cost of creating rail infrastructure, long gestation periods and time required for creation of new infrastructure it may be difficult to provide for a higher growth rate than 7% in Non-suburban traffic and 4% in Suburban Traffic. Moreover the total growth envisaged will have to be catered for by IR railway network, new Urban and Regional networks coming up under the ambit of the Ministry of Urban Development like the RRTS and Metro systems in new cities as well as the High Speed Rail Systems that have been planned.

9.3.3 Some Other Shorter Term Projections

1. IR Vision 2020 Document: Published in late 2010 the document had made projections for the year 2020. For the period between 2011-12 and 2019-20 it had considered a growth rate for originating passengers of 8% CAGR and passenger kilometres of 10% CAGR and projected traffic for 2019-20 at 15180 Million Passengers and 2360 Billion Passenger Kilometres. The growth rate achieved over the last few years has been much lower than these projections and this level of traffic despite low tariffs is not likely to be attained.

2. 12th Five Year Plan: The Planning Commission in the 12th Five Year Plan Document has projected originating passenger traffic based on average correlation with GDP calculated for the preceding 5 years. For the year 2016-17 it has projected 11.71 Billion passengers including 5.92 Billion Suburban and 5.79 Billion Non Suburban passengers. Similarly Passenger Kilometres have been targeted at 207 Billion in case of Suburban and 1553 Billion in case of Non Suburban. The Passenger Kilometres have been compiled at a growth rate of 10.8%. This projections are somewhat higher than what has been indicated in Para SS-9.3.2 above and again in the first two years of the plan the actual budgetary target of the Railways is significantly lower.

9.3.4 Projection from an Expert Study

A paper published for the International Transport Forum (A Vision for Railways in 2050' a former

World Bank Expert Louis Thompson) has given projections for passenger kilometre growth in India that were made by the author in 2000 based on assessment of GDP growth and a method of indexing. The projection as the author himself has admitted was basically to try and establish a crude growth trend. In this assessment projected for the year 2035, 1057 Billion Passenger Kilometres and a growth factor of 4.4 over a period of 50 years from 2000 to 2050 were estimated. The 2035 projection has already been attained in 2013. This only highlights the hazards and difficulties of making projections over the long term future.

9.3.5 International Transport Forum Assessment for Non OECD Countries

The International Transport Forum monitors global trends and makes projections for 2050 for Passenger & Freight traffic broadly for OECD and Non OECD Countries. Non OECD countries are the developing nations like China, India and others. In their Transport Outlook for 2012 they have indicated the growth pattern for Passenger Kilometres all modes up to the year 2050. This projection forecast is High and low GDP growth scenarios with high and low car ownership. What the scenarios indicate is that by 2050 in developing countries private mobility will grow 3.5 times and by the year 2037 should grow by 2.6 times (see Fig.6)

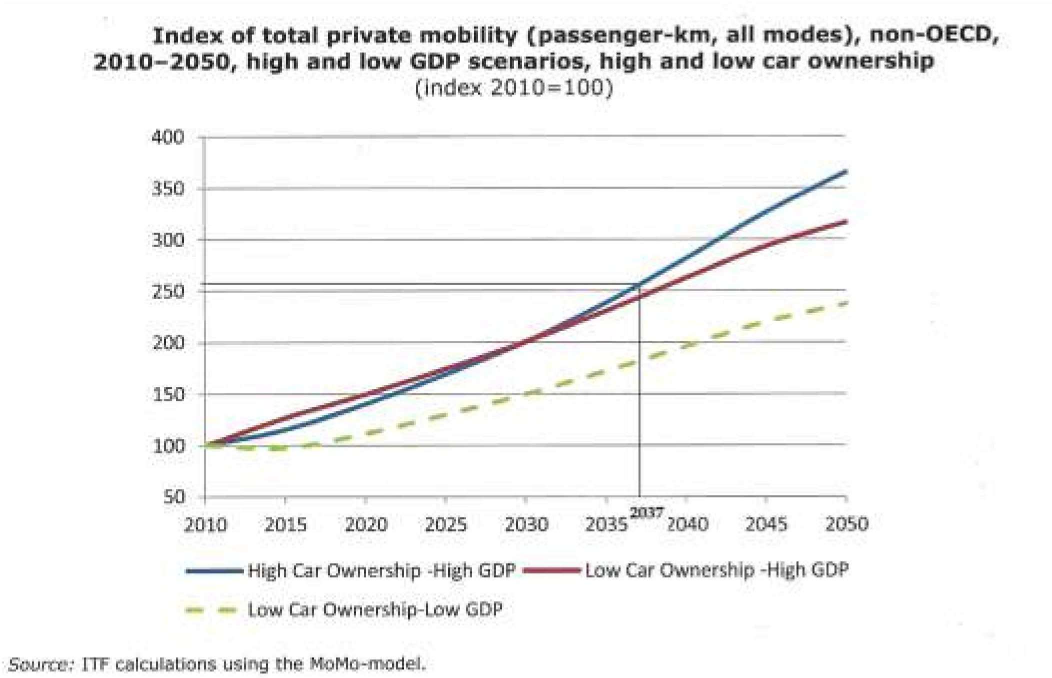


Fig. 6: ITF Index of Total Private Mobility (Pass. Kms.)

Index of total private mobility (passenger –km, all modes), non-OECD, 2010-2050, high and low GDP scenarios, high and low car ownership

In India, quite definitely, the trend shown in this scenario will be exceeded and growth by 2037 could be much higher (7 times as per projections in Para SS-9.3.2). India does differ from other developing countries in terms of higher GDP growth, better infrastructure, particularly, a strong base in Railways (highest passenger carrying Rail system in the world), very high percentage of population in working age group, potential for very high rural – urban shift in population and unprecedented growth in middle class population during the period.

9.3.6 Conclusion

The Railway Systems in India will go through a period of tremendous growth in passenger traffic volumes over the next 24 Years and the system will find it extremely difficult to cater to demand. Some check on the growth rate must be exercised through suitable pricing interventions. However, creation of line capacity, development of new terminals, maintenance facilities and production of coaches needs to be taken up on a war footing. The Passenger business, in fact all segments of it must become self sustaining. Achieving and sustaining growth and meeting demand that are going to be placed on it are a major challenge for Indian Railways.

The Passenger Traffic volume estimates for the year 2037 are as under*:

	No. of Passengers	Passenger Km	Length of Trip	(i)CAGR - No of Passenger & (ii) CAGR – Trip Length
Suburban	**11,640 Million**	**487,729 Million**	**42 Km**	**(i) 4% (ii) 1%**
Non Suburban	**20,792 Million**	**7,858,879 Million**	**378 Km**	**(ii) 7% (ii) 2%**
Total	**32,432 Million**	**8,346,607 Million**	**257 Km**	

The corresponding Passenger Traffic volume for 2012-13 are as under:

	No. of Passengers	Passenger Km	Length of Trip
Suburban *	**4,541 Million**	**149,460 Million**	**33 Km**
Non Suburban*	**4,099 Million**	**967,442 Million**	**236 Km**
Total*	**8,640 Million**	**1,116,902 Million**	**129 Km**

9.4 POLICY / TECHNOLOGY INTERVENTIONS NEEDED

9.4.1 Need for Accelerated Development of Rail Capacity

For efficient and effective performance of a transport system, on a sustainable basis, following three areas need proper attention and inputs :

(i) Maintenance of existing assets – Fixed, Moving, and Others.

(ii) Expansion of the Network – As for example, New lines and additional parallel lines (Doubling; Three Lines; Quadrupling) on a Railway System, along with necessary support facilities.

(iii) Modernisation - On the Indian Railways (IR), all the three areas have suffered primarily due to paucity of resources and policy of advantage Road vis-à-vis Rail. However, extreme concerns for Rail safety, voiced by media and public, have resulted in investments in Maintenance and Modernisation to a large extent but the Expansion of Network had lagged far behind.

9.4.2 Projected Rail Traffic Growth

The Traffic Projections for 2037-38 with 2012-13 as Base Year envisage a Compounded Annual Growth Rate (CAGR) of 5% for the Originating Freight Traffic, 4% for Sub-urban Passenger Traffic and 7% for Non-suburban Passenger Traffic. While some planners may argue that Traffic growth will be higher, it will be appreciated that even with the assumptions made the Rail Traffic will become 3-4 times the existing levels in next 25 years. Such an increase will need directed Policy, Financial, Technology, Engineering and other inputs. In addition, the Transport Planning will have to ensure Integrated Development of various Transport Modes (Rail, Road, Water, Air) to achieve optimum results.

9.4.3 Need for Three Policy Directions

9.4.3.1 *Level Playing Field to Rail vis-à-vis Road*

In India 91% of the traffic is carried by Rail (31%) and Road (60%). For carriage of freight traffic, Rail is nine times fuel efficient vis-à-vis road but is loosing its market share (from 89% in 1950-51 to 30% as of now) resulting in enhanced pollution for the transport sector as a whole. Earlier efforts to contain this decline in Rail's market share have not succeeded but the environmental concerns now necessitate urgent action to rectify the situation. The main reason for the Rail to loose vis-à-vis Road is that 'social costs' are not suitably factored in. While authentic data in this regard is not available for our conditions, a recourse to other international studies clearly highlights that its impact is substantial.

This also highlights the need for a detailed Study and evaluation of the Social Costs for our conditions, and, till this is done, to provide inputs to Rail on the same pattern as being done for the Road - very much like the National Highways Development Programme (NHDP) and the Pradahan Mantri Gram Sadak Yojana (PMGSY). As a matter of fact Rail should be given some further inputs so that the skewness already created could be rectified with speed.

9.4.3.2 *Rail to correct its Tariff Ratio*

Once a level playing field is provided to Rail vis-à-vis Road, the Rail tariffs can be fixed in a more rational and pragmatic manner. In such a situation, the Indian Railways can plan to correct the Tariff ratio (Ratio between the average passenger fare per km to the average freight rate per tonne km) from a value of around 0.3 to a value of about 0.5, as was existing in the year 1950-51. Cross subsidising passenger traffic at the cost of freight traffic, is not desirable. This correction could be accomplished by suitably enhancing the passenger fares and/or reducing the freight rates and will generate some extra revenue for the IR which could be gainfully utilized in the development of facilities for the passengers.

9.4.3.3 *Formation of a Centralised Metro Rail Transport Authority*

Metro Rail projects are not only essential to carry heavy urban traffic but also considerably reduce environmental pollution. The Integrated Energy Policy of the Planning Commission, August 2006 lays special emphasis towards development of rail-based urban transport systems in major cities to conserve fuel/energy. Construction of metro rail projects in our country has lagged behind very much. Even though urban transport is a State subject , the Metro Rail projects need highly specialized knowledge and inputs. To give a boost and direction to this activity constitution of 'Centralised Metro Rail Transport Authority' appears to be a necessary. This will ensure faster and effective coordination between the Ministry of Urban Development, Ministry of Railways, concerned State Governments, Urban Local Bodies (ULBs) and other Stake holders.

9.4.4 Two National Projects

Expeditious development of Rail transport capacity on busy routes and development of rail network in the country are being suggested. The IR is taking action in this regard and have also developed a Vision 2020 document and an Action plan. However, to ensure timely availability of adequate rail infrastructure it will be desirable for the Government of India to undertake the following two rail projects as National Projects:

I. Dedicated Freight Corridors (DFCs) – See Box 1.

Box 1 : Dedicated Freight Corridors on the Indian Railways

- The Golden Quadrilateral (connecting four metro cities of Delhi, Kolkata, Chennai and Mumbai) and its two diagonals, which constitutes about 16% of Route Kms or 25% of Running Track Kms carries more than 55% of the traffic of the Indian Railways (IR).
- Dedicated Freight Corridors (DFCs) are planned for the entire Golden Quadrilateral and its two diagonals by laying two new parallel double lines exclusively for freight traffic thereby making the existing system a passenger corridor. The approximate length of six DFCs (Four sides of the quadrilateral plus two diagonals) will be 11,500 km of double line (23,000 km of rail track). The DFCs will mostly run parallel to the existing system but in busy areas and yards detours will be necessary. Currently, work on Eastern and Western DFCs is already in progress.
- Existing network is mostly a double line section (except for some stretches where 3rd or 4th lines exist) and the construction of DFCs will virtually mean quadrupling (Two Passenger lines + Two Freight lines) of the sections. With four lines, increasing traffic, and improving average speeds of trains (due to enhanced mobility) the operation of existing level crossing (surface crossings of road and rail) will not be practically possible and so grade separation becomes an essential prerequisite, needing provision of Road Over Bridges (ROBs) or Road Under Bridges (RUBs) in lieu of existing level crossings.
- The existing axle loads on the IR system are 20.3t and have recently been enhanced on some selected routes to 22.9t. The DFCs are being designed to take axle loads of 30.0t and for the present 25.0 t axle load wagons are proposed to be run for which Feeder Routes (about 30,000 km; axle load 22.9t) are also being upgraded to enable carriage of 25.0t axle load wagons.
- Container traffic will be growing faster than the normal traffic. Accordingly, running of double stack container trains is contemplated on the DFCs and overhead clearances of structures like Road Over Bridges (ROBs), Foot Over Bridges (FOBs), Tunnels etc. are being planed accordingly, also keeping in mind the aspects of electrification of the lines now or in future. For heavier traffic, electrification of routes proves to be a more economical proposition in addition to an overall reduction in the consumption of energy vis-à-vis use of fossil fuels.
- Construction of DFCs will greatly enhance capacity and mobility, mainly due to the following :

  (a) Slow moving goods trains (75 kmph/100 kmph) will not come in the way of passenger trains (100 kmph/140kmph) nor the slow moving freight trains will have to wait for giving precedence to faster moving passenger trains. This will reduce congestion and improve average speeds of both the passenger and the freight trains. The sectional capacity will also markedly improve.

(b) Higher axle load wagons plying on DFCs will carry more load per train.

(c) Existing corridors (passenger corridors) will be relieved of heavier freight trains thus giving relief in maintenance especially to old existing bridges.

(d) Since level crossings will not be existing (complete grade separation), the existing passenger corridors could run normal trains at 160 kmph speeds as also tilt body passenger trains upto speeds of 200 kmph (similar to Swedish X2000) by suitably fencing the existing tracks and providing cab signalling. This will also enhance safety of travel.

(e) The Rajdhanis' which currently run at a maximum speed of 130/140 kmph and take about 16 hours for journeys between New Delhi and Mumbai and about 28 hours between New Delhi and Chennai may be able to cover these distances in about 11 and 18 hours respectively.

- Completion of DFC project, in a period of about ten years is essential to meet the growing traffic demands (traffic is likely to double in next 7-10 years). However, it will be a difficult and challenging task involving construction of about 2300 km of rail lines every year.
- Completion of all the six DFC lines (Quadrilateral and two diagonals) in about ten years will not be possible unless adequate funds are assured. In this regard, Government of India should consider providing 40% of the Project Cost as a Grant in the form of Viability Gap cum Accelerated Development cum Environment Mitigation Fund.
- It will be desirable to execute the DFC Project as a National Project in view of its importance to the country's economy. A special purpose vehicle (SPV) viz., Dedicated Freight Corridor Corporation of India Limited (DFCCIL) of the Indian Railways is already in place and work on the Eastern and Western DFC corridors is currently in progress.

2. Construction of 10,000 Km of New Railway Lines @ 1,000 Km/yr.

- New Railway Lines are being constructed at a very slow pace, primarily because of fund constraints and their financial non viability. Since 1950-51, only 21% addition has been done to the Route Kms which indicates that the pace of New Line construction has been about one third of what it was in the 100 year period prior to Independence (1947).
- Such lines open the system to traffic from new markets and are also needed to develop rural areas including the vulnerable 'border' areas. In addition to generation of employment during construction and subsequently for the maintenance and operation, such lines generate considerable amount of employment in the related non-railway sectors. Environmental consideration also necessitate improved transport share for Rail clearly pointing towards the need for expeditious growth of the Rail network.
- Some may argue that such lines are not necessary for the Indian Railways (IR) but more than 11,000 km New Line projects already sanctioned (IR Vision 2020 – Dec. 2009) and waiting to be executed tell a different story. The progress of New Line construction in the pre-Independence era was more than 500 km/yr which reduced to about one third (about 180 km/yr.) after the Independence (1947). The five years (2004-05 to 2008-09) have seen a construction rate of about 230 km/yr. (IR White Paper - 2009). The need for a major thrust

towards this vital area of Network Expansion has been recognized and the IR's Vision 2020 document suggests a growth rate of 2500 km/yr for the New Lines which has been scaled down to 1000 km/yr in the Rail Budget (24th Feb. 2010). The target of 1000 km/yr appears more pragmatic but even for it funds will be a major constraint. It is suggested that construction of New Railway Lines should be considered in the same light as the Pradhan Mantri Gram Sadak Yojna (PMGSY) and the Government of India (GOI) should consider a support for this vital need in the form of viability gap cum accelerated development cum environment mitigation fund. Other inputs like the rolling stock, operation and maintenance costs, and the allied losses for such lines could be borne by the IR.

9.4.5 Need for a National Transport Authority

There is no centralized monitoring authority/institution for regulating coordinated operation and integrated growth of different transport modes in our country. Authentic relevant data is also not available for our conditions. The current environmental scene necessitates much greater weightage towards 'social costs' and it has to be duly reflected in the optimization process in addition to the usual 'economic costs'. There is an urgent need to have a National Transport Authority for the purpose and also for taking further action on the Three Policy Directions elaborated in earlier.

9.5 THE VISION FOR INAE INITIATIVES

The preceeding part of the note has brought out the need for addressing the problem of skewness in the Rail/Road usage in the interest of tackling environmental issues among other reasons. Further, the development of multi-modal transport systems has its merits, particularly with the emphasis on growing urbanization. Besides, an approximately eight-fold growth in the capacity to carry passenger traffic, and three-fold growth in freight traffic from the present to the year 2037 is projected, which, is inescapable. Construction of Dedicated Freight Corridors, large lengths of additional rail tracks and the upgradation of existing facilities will throw up a plethora of technological and other issues. It has been suggested that a 'National Transport Authority' be set up to look into the various facets of the upcoming developments and as to how these can be tackled. Similarly, it is suggested that a 'Centralised Metro Rail Transport Authority' be established.

The INAE should work on evolving related policy documents, which can be considered suitable for implementation, duly interfacing with the Indian Railways and the different stakeholders such as R&D institutions, the construction industry, the Governmental agencies planning of infrastructure and those dealing with Environment concerns. A multi-disciplinary INAE Forum on Infrastructure, as also suggested in an earlier Sector, will help in pursuing this vitally important subject area with intensity and due continuity. The INAE should also take up research studies on related Technological aspects for the development of the railways, which run across different disciplines of Engineering.

The Indian National Academy of Engineering (INAE), founded in 1987, comprises India's most distinguished engineers, engineer-scientists and technologists covering the entire spectrum of engineering disciplines. INAE promotes the practice of engineering and technology and related sciences to solve engineering and technology related problems of national importance. The Academy provides an active forum to plan for the country's developmental activities that require engineering and technological inputs. Its other activities include formulation of technology policies, and promotion of engineering education and research & development. INAE represents India at the International Council of Academies of Engineering and Technological Sciences (CAETS).

Indian National Academy Of Engineering