3. RESEARCH IN ENGINEERING AND TECHNOLOGICAL INSTITUTIONS IN INDIA: CURRENT STATUS, OPPORTUNITIES AND CHALLENGES

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Abstract

This paper attempts to identify research and innovation as a major untapped potential of Indian talent in the emerging knowledge economy. If India is to exploit its demographic dividend potential, it must focus on knowledge creation, dissemination and application with quality in each of these, as the guiding philosophy. However, the current scenario of research – and particularly quality research in engineering and technology in the country, is quite disappointing. The ratio of undergraduate to post-graduate and research scholars in engineering colleges is heavily imbalanced in favor of undergraduates which are perceived as 'star' programs or 'cash cows' but research is seen as a cost center which has long term returns. About 80% of Ph.D. degrees awarded in engineering and technology are being produced by IIT's / NIT's / IISc., though these institutions account for less than 5% of total undergraduates in engineering and technology. The paper employs concepts like SWOT Analysis, Theory of Constraints (TOC) and the BCG matrix to look at the academic degrees as academic products of an engineering college. The quality of research and its relevance to national needs is also a question mark. Due to manifestation of the 'Diminishing caliber Syndrome', the quality of inputs to research programs is below par of the quality of lower degree programs of the same institute. Status of research publications in peer-reviewed international standard journals is also quite pathetic. To improve the situation and take a lead in emerging knowledge economy, a strategic roadmap is proposed to boost research in engineering colleges in close collaboration with industry.

1. Introduction

Engineering and technology are the engines of growth and development of a nation as it enhances quality, productivity of products and services. Innovation through research and development intensifies the potential of technology to improve competitiveness. In this context, research and innovation becomes a vital pre-requisite for a nations' prosperity through technological means. In the increasingly global and knowledge driven economy, the role of educational institutes of engineering and technology in knowledge creation, dissemination and application becomes pivotal.

It is important that, at least in the context of higher technology institutions, these three sub-functions of an educational institution must be perceived in an integrated and balanced manner and not in an either / or framework. It

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is teaching and research both, rather teaching or research, that should be the goal of an engineering college or a technical university because these are inseparable part of faculty's role.

Unfortunately, in Indian technical education context, the research and innovation has not been given the prominence, it deserves. For example; in India, around 1000 engineering Ph.D. degrees are estimated to be awarded every year, 80% of these are coming from IIT's / NIT's / IISc; whereas in USA, in the year 2007, 921 PhD. Degrees were awarded in Chemical Engineering alone, whereas in Bengaluru – a premier research institute awarded 12 Ph.D.'s in Chemical Engineering during 1996-2005, which on an average works out to 1.2 / year. Thus, India produces only about 3% of Chemical Engineering Ph.D.'s per year compared to the USA. Total Ph.D.'s produced in USA is around 32,000 per year compared to nearly 1000 in technology and engineering in India. In contrast, India produces nearly six lakh engineering graduates compared to 1 lakh plus in the USA. From this, it can be inferred that research is not a priority agenda in engineering and technical education in India. Figs. 1 and 2 compare the trends of post graduates and research in USA, China and India(Wadhwa,6).

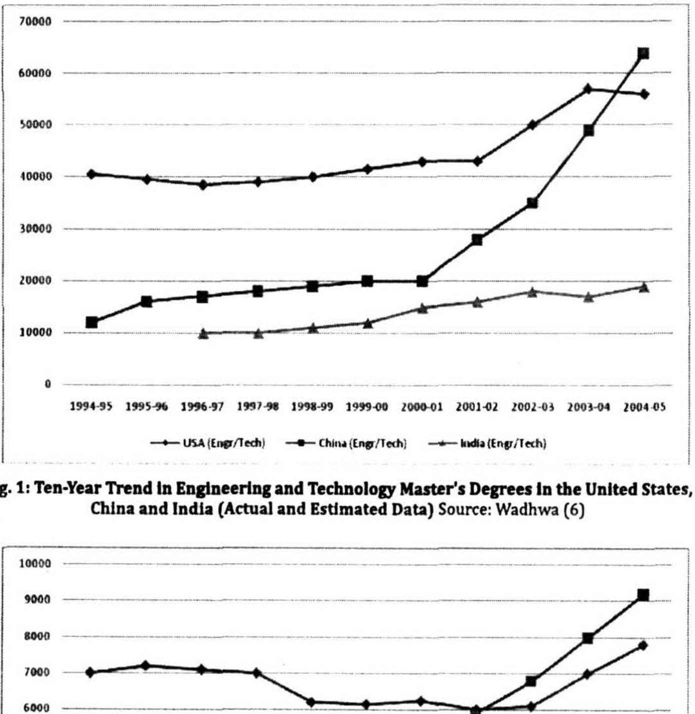

Fig. 1: Ten-Year Trend in Engineering and Technology Master's Degrees in the United States, China and India (Actual and Estimated Data) Source: Wadhwa (6)

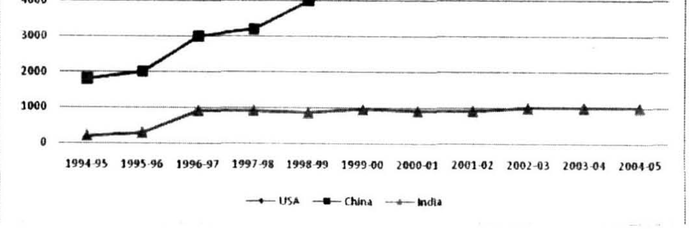

Fig. 2: Trend of Engineering and Tech Ph.D. Degrees in the United States, China and India Source: Wadhwa (6)

2. Status of Research in Engineering and Technology in India

Status of research in a country can be measured through a number of performance indicators such as – number of Ph.D. degrees being awarded every year; number of peer reviewed research papers with significant impact factors or citation – index being published / year; number of patents filed or given, percentage research budget allocated out of total budget of the institution or university and percentage of budget for R&D in a company out of annual turnover or profit of that company. Perhaps, a more balanced measurement will be, a judicious combination of all of these. If we examine each of these performance indicators for India and carryout global comparisons, perhaps on each count, we will find that Indian higher education system and industry are lagging substantially behind, not only the developed nations, but even our nearest neighbor -China, which graduates more than double the engineering graduates compared to India; yet its Ph.D. graduates are nearly 10,000 per year compared to less than 1000 in India (Fig. 2,Wadhwa). At postgraduate level, while India produces nearly 20,000 M.Tech's per year; China has overtaken even the USA with around 65,000 masters degrees given every year. On publications front too; India is far behind China in the percentage share of research papers in science and engineering, both in terms of numbers per capita and the citation count. India was having in the past the English language advantage over China but is fast loosing that edge as China is learning English language with a feverish pitch. Therefore, in future this situation may get further aggravated. If we examine the R&D investments; in India less than 1% of GNP is spent on R&D compared to 3-4% in the developed world. Indian industry spends less than 1% of its sales turnover on Research & Development. This, in turn impacts adversely on the employment of and incentives for doing Ph.D. and M.Tech. degrees, who should be employed as R&D scientists and engineers. Little or no interest of graduate engineers to pursue M.Tech. / Ph.D. basically emanates from this indifference of Indian industry towards research. It does not augur well for the global competitiveness of India.

There are more than 18 technical universities in India affiliating more than 3000 engineering colleges. All these put together may be producing about 150-200 Ph.D. degrees and 3-4 thousands of M.Tech. degree holders only. Quality of many of these degrees may not match international standards. Thus, quantity and quality of research programs in Indian affiliated engineering colleges are a cause for serious concern. Similarly, the global share of India in peer reviewed engineering and technical journals is around 1.5% coming from a population share of more than 16% of the world, 55% of whom are less than 25 years of age. These statistics are worrisome and indicate that research and innovation is a neglected component of engineering education in India.

In a recent CII- INSEAD study on global innovation index 2009-10, India is ranked at 18th place among Asia and Middle East region with a GII (Global Innovation Index) of 3.10 on a 5-point scale whereas Hong Kong, China is at first place with a score of 4.83 and Singapore at 2nd place with a score of 4.65. Nepal and Syrian Arab Republic have the lowest score of GII at 2.35 and 2.13 respectively. In Americas, US is at number one place in GII with a score of 4.57. South Africa in the African region is at first place with GII of 3.24. Thus, there is enormous regional and inter-continental variations in the global innovation index. India stands at a rank of 56 globally. On research publication front, it ranks 78 and on number of patents it ranks 74. However, it ranks 35 on capacity for innovation. Thus, it is obvious from these global rankings that there is a disconnect between the capacity and actual outcome from that capacity of research and innovation. Research and researchers do not get the social esteem and economic compensation that their other counter-parts in industry and government service have. This is perhaps the reason for research and teaching being among the least preferred career options of the best and the brightest of the society, perhaps leading to the diminishing caliber syndrome.

SWOT Analysis of Research in Engineering and Technology in India

SWOT (Strengths, Weakness, Opportunities, Threats) analysis is a very insightful yet simple tool for organizational soul searching .In the context of importance, quality and quantity of research in engineering colleges and institutes; it can unfold the reasons for low research output as well as strengths that can be leveraged to enhance research output. Strategic roadmap can then be developed to exploit opportunities by leveraging strengths, removing the weaknesses and guarding against threats. Some of these (not exhaustive) are listed as follows:

A. Strengths:

1. Large demographic dividend with more than 55% of people below the age of 25 years, available for doing research, if motivated.
2. Large and highly innovative and creative mind which is strong in analytical skills and can find out of box solutions to fix problems, if they find a purpose in it.
3. Majority of very brilliant students after 10+2 prefer to study professional courses like engineering, technology and medicine. Thus engineering colleges are brain banks and can be utilized to enhance research culture in colleges.
4. Huge private equity participation in technical education system leading to more than 6 lakh engineering graduates being added to talent pool every year. There are more than 3000 engineering colleges being controlled by technical universities. 95% of these colleges are private funded with very good physical infrastructure. Thus, India has attracted a huge amount of private equity in engineering education sector. Such an investment would have been difficult to come from government sources alone.
5. Best innovative potential of students is realized when they are involved in challenging innovative R&D projects as a part of pedagogy rather than rote learning. If colleges can give research projects to UG students in final year, they can do wonders.
6. A huge, nationally distributed CSIR research laboratories network, DRDO labs, exist in the country which have modern technological facilities that can be used for students -driven R&D projects through the synergy of these labs and engineering colleges under joint supervision of scientists of these labs and faculty of those colleges.
7. There is a large potential of socio-economically relevant problems that could provide exciting research projects for improving the quality of life through means of technology.

B. Weaknesses:

1. Lack of research mind-set that fails to attract brilliant scholars to pursue research as a first choice.
2. Inadequate and research-wise unqualified faculty to guide research projects and create a right kind of research ambience in the engineering colleges. It is estimated that in most of these private engineering colleges, hardly 5% of engineering faculty will have a Ph.D. degree and about 20% might have M.Tech degree. The demand and supply of Ph.D. faculty in engineering and technology is so huge that at the current rate of Ph.D. degrees being produced, it may take 20 years to bridge the gap at current rate of requirements.
3. Very poor budget allocated for research in the engineering colleges. It is almost negligible, if we leave IIT's / IISc. / NIT and some established universities. The research

equipment, facilities are frustratingly inadequate in most engineering colleges.

4. Research is perceived by the ownership and academic leadership of these colleges as cost centers with inadequate return on investment made in research. Research just dos not fit into the 'business model' for managing such institutions.

5. No or low interaction between R&D departments of Indian industry, CSIR/DRDO labs. and similar organizations with engineering colleges resulting in almost no relevant research degree level or sponsored research programs. Almost 80% of sponsored research funding from the government and industry is focused on 15-20% of institutions in the country.

6. Non availability of attractive research fellowships offered by the private sector in the engineering colleges to pursue research work.

7. More than 50% attrition rates of research scholars pursuing research in engineering and technology. Many a times a research program is perceived as a stop-gap arrangement until one gets a good placement in industry. Research fellowship, at times becomes almost a dole to sustain the scholar financially till he/she finds a job.

8. Dearth of good quality, peer reviewed, internationally benchmarked research based journals in India which have a good impact factor and citation value. Most Indian journals do not get covered for citation purposes. As a result, very good quality research papers are sent abroad and then we import costly foreign journals back while quality of papers in Indian journals is highly variable from low to medium with only occasionally a great quality paper being published. This calls for change of mind- set in recognizing faculty publications in Indian journals; otherwise, the vicious circle will never get broken. India must promote likes of ASME, ASCE, IEEE journals and the faculty must like their papers being published from India.

9. Very low employment potential of M.Tech. / Ph.D. in Indian industry. Generally, pursuing Ph.D. is perceived, as the person to be cut-out for teaching only which in anyway is not an attractive career option.

10. Technical university does not liberally recognize colleges to be the research centers. Most of Ph.D. programs are centrally controlled by the affiliating university leading to delays and bureaucracy. For example, in a typical technical university, RDC (Research Degree Committee) is chaired by vice-chancellor and the secretary is the Registrar. With 20 RDC's, it is almost impossible for the two functionaries to be present in all or most meetings. Scheduling of meetings are occasional and this leads to slow processing of registration, progress monitoring, thesis submission, defense etc. which impacts on the scholar's morale and enthusiasm. Lead time for getting thesis examined is large and in many cases ICT is not used to expedite it.

11. The diminishing caliber syndrome plagues the quality of research student inputs. It is normally seen that from academic brilliance point of view, B.Tech. students are the brightest, followed by M.Tech. followed by Ph.D. students. Logically it should be the other way round – only best of B.Tech. students can pursue M.Tech., only best of M.Tech to pursue Ph.D. But system does not attract the best brains to join teaching / research.

12. Undergraduate students are not involved in research projects. Some limited experiments have revealed that if colleges involve B.Tech. students in innovative research projects – particularly with industry support, the research culture gets created even without PhD. Scholars. Once these students enjoy research work , may be they will opt for research as a career later on.

13. Most of the research funding in India is from the government sector – DST, DBT, AICTE, UGC. Perhaps 95% funding comes from this source, whereas industry supports about 5% research budget of engineering colleges. In developed countries almost 80% research funding comes from industry. This affects quantum, monitoring and outcome of research.

14. Facilitation of IPR is very weak. It takes long time to get patents filed and approved. General awareness level of IPR is low.

C. Opportunities

1. Increasing demand for Ph.D. degree holders in teaching/research organizations due to enormous shortage of faculty due to expansion of technical education.

2. Retirement age of teachers has been increased up to 70 years which gives 10 more years to working life for professionals retiring at 60 in industry and government. Thus, a large number of senior (late bloomers) in 45-60 years age group would like to do Ph.D. in engineering to increase post retired work life by 10 years. This can only be availed by permitting part-time M.Tech. / Ph.D. registration in colleges to meet the demand supply gap.

3. KPO's – Knowledge Process Outsourcing and off-shore R&D centers make India a preferred location. Lots of Ph.D. holders in engineering and technology may be hired by MNC's R&D centers in India making Ph.D. degree a good attraction in colleges / technical universities.

4. ICT enabled research academies could facilitate Ph.D. – particularly coursework in a virtual class room environment to encourage increased registration.

5. Foreign universities bill, if through, will create quality based competition for talents; thus increasing the value of holding a good Ph.D. degree.

6. Private universities coming up in a large number can give a major quantitative push to research degree programs in a big way. The only caution to be exercised is that quality should not become a casualty in the rush for quantity.

7. Dual degree (B.Tech and M.Tech.) an integrated research (integrated M.Tech. / Ph.D.) programs can ensure quality inputs to research program and is a good opportunity.

D. Threats

1. Unreasonable gap in the monetary packages offered by corporate world in comparison to teaching and research. This will prevent to attract the best brains to teaching and research.

2. Ignoring basic, fundamental research will impact even the applied research in the long run.

3. War on talent – newer universities IIT's, NIT's, IIM/s and possible foreign universities will intensify war for talent hunt and shortages will get spread out.

4. Unbalanced age profile in engineering colleges with faculty either 60 plus or 20 plus in age may threaten sustained research ambience because a strong research based middle cadre is required for research to be sustained over a long period. Visiting or on contract fresh faculty may not be enthused to initiate research programs, projects as their gestation period is high.

5. Myopic perception or business model of private entrants to education field may rule out research as an option.

6. Importing technology rather than 'home grown' syndrome may put research and development and product innovation on a back burner.

7. Lack of 'psychic income' in educational

institutions. In many colleges, the faculty is treated like a 'work force' required to sign attendance – at times bio-metrically. General respect and esteem enjoyed by them at the hands of the management – particularly family owned - is not very conducive to research, being a creative process. Creative process is not time bound like assembly line output and the performance is not linear function of time – nor the economy of scale model would work in research. Talent needs respect, self-esteem, academic freedom, autonomy, spirit of exploration which constitutes 'psychic income' over the financial package. It is not common in Indian private or family owned engineering colleges. Hence, no research is possible under such a mechanistic approach to faculty members.

SWOT analysis can be effectively used to develop strategies for enriching the research programs by exploring the following TOWS matrix approach:

1. SO - Maxi-Maxi Strategy :
   Use strengths to maximize opportunities

2. ST - Maxi-Mini Strategy :
   Use strenghts to minimize threats.

3. WO - Mini-Maxi Strategy :
   Minimize weaknesses to maximise opportunities

4. WT - Mini-Mini Strategy : Minimize weakness to avoid threats

BCG Matrix and Ph.D. Degree as an Academic Product

Boston Consulting Group (BCG) has developed a powerful but simple matrix (BCG Matrix) to identify products offered by a company in four quadrants based on 'market share' and 'market growth'. It groups products as 'Stars', 'Cash Cows', 'Question Marks' and 'Dogs' (unusual term). In this paper, an attempt is made by the author to treat academic degrees given by a technical university and from the 'IIT system' on BCG Matrix as the academic product offerings. Fig. 3(a) shows a BCG Matrix for a technical university and 3(b) shows a similar matrix for 'IIT system'. The grouping is tentative and perceptual. This can be dynamically modified.

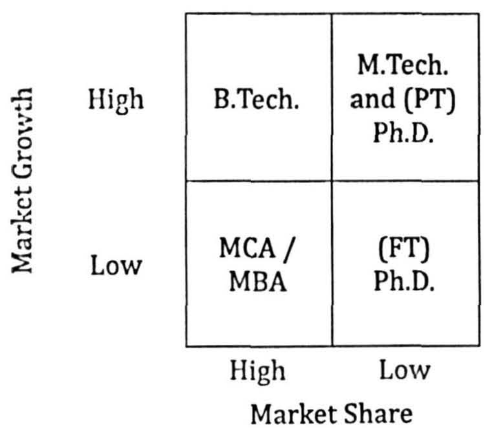

Fig. 3(a) BCG Matrix for Technical University

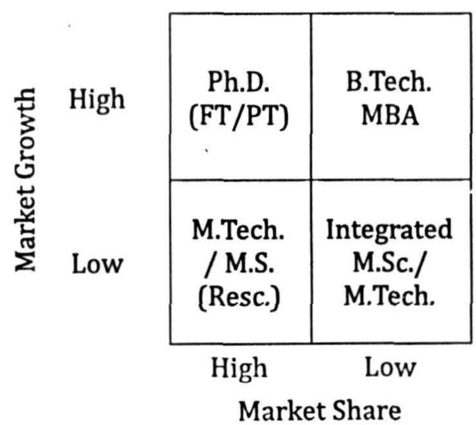

Fig. 3(b) BCG Matrix for IIT System

It can be seen from the BCG Matrix for technical universities that B. Tech. program is their 'Star Program' while 'MBA, MCA' may be a 'Cash Cow'. M. Tech. and (P.T.) Ph.D. may be 'Question Mark' while full time Ph.D. is 'Dog' in terms of Matrix terminology. Thus, full time and part-time Ph.D. are either question mark or as a dog. Perhaps there is a need to convert 'B. Tech.' into 'Cash Cow' and divert extra resources created by such cash cows to make M. Tech., Ph.D. (PT) as 'stars' and upgrade (FT) Ph.D. to at least a'?' status.

In contrast, the BCG Matrix for the IIT system has Ph.D. degrees (FT and PT) as 'Star' products because the market share is higher (nearly 65% of total engineering Ph.D.'s are from IIT system in the country) and due to heavy demand in the market due to faculty requirements and expansion of technical education system, the market growth is also very high. M.Tech., MS (Research) is perhaps 'Cash Cows' (not in financial terms) due to high market share but low growth rate. Integrated M.Sc., M.Tech. programs are perhaps 'dogs' and B.Tech., MBA is a 'question mark'. It is counter-intuitive to consider 'B.Tech. of IIT's as 'question mark' as the society perceives them to be the 'star' programs. That is a perception based on demand due to perceived superior quality of these undergraduates. However, more objectively, in BCG matrix term; IIT's should seriously debate about thier B.Tech./ MBA programs as the main objective of IIT system at the concept stage was to focus producing outstanding quality M.Tech. and Ph.D.'s only to enrich the B.Tech. quality of technical university and also for upgrading their research culture. This is a powerful insight though on the face of it appears counter intuitive and unacceptable.. The role of a model is to refine intuition and it is evident in this case. Perhaps it needs debate.

The regulatory authorities in the country in charge of technical education system should re-examine the policy of restricting part-time M.Tech. / MBA and Ph.D. programs in private engineering colleges affiliated to the technical university in order to expand the post graduate and research base of these colleges. Unless, teaching and research are seen as two sides of the same coin, academic excellence would not come. Thus there is an urgent need for policy review of course; ensure meticulously quality dimension and in no case, it should be allowed to be diluted.

Theory of Constraints (TOC) View of Technical Education System

Theory of Constraints (TOC) is an overall management philosophy geared to help organizations achieve their goal. It opines that any system of management is limited in achieving more of its goals by a very small number of constraints; and there is always, at least, one constraint. The TOC process seeks to identify the constraint and focus rest of the organization around it through use of five focusing steps. These are:

1. Indentify the constraint – the resource or a policy that prevents the organization from achieving the more of the goal.
2. Decide how to exploit the constraint (get the most capacity out of the constrained process)
3. Subordinate all other processes to above decision (align the whole system or organization to support above decision)
4. Elevate the constraint (make other major changes to break the constraint)
5. If some other resource or policy has become a constraint, return to step 1.

If TOC is applied in the context of the goal of enhancing research in engineering colleges and universities; the shortage of qualified (Ph.D. degree holders), experienced and capable faculty resources is that key constraint which is the bottleneck constraint. Therefore, everything in engineering colleges should be organized around the faculty constraint and there must be efforts to reduce this constraint by faculty recruitment, motivation and development to attract, retain and motivate talented and qualified teachers having a doctoral degree. Most of the strategic roadmap to enhance research output should be based on getting most out of this capacity constraint by creating an enabling and inspiring research ambience in the engineering colleges. Absence of research ambience prevents talented faculty to get attracted to join teaching and research as a career option. To get most research output from the faculty, the college must invest in research facilities, library ,computational support and recruit a large number of full time as well as part-time research students under the mentoring and supervision of professors. There should be at least two research students with every faculty qualified to guide research and the college should earmark at least 10% of its annual budget on research. It must incentivise faculty who guide and publish to get more emoluments as performance incentives. MDI, Gurgaon has evolved a very good point system which encourages faculty to guide research and publish in reputed journals.

Simultaneously, the engineering college should have eminent retired professor and scientists with track research record and a doctoral degree to be hired on contract as Research Professors / Research Mentors or Honorary Visiting Professors on token honoraria, conveyance and decent office space to nurture, guide young research students and faculty. Such mentors will be able to contribute with dignity and country will benefit from their research talent. To succeed on this front, college management must ensure not to treat them as employees but 'gurus', whose affiliation will bring glory to the college. In India, the irony is that on one hand we are facing acute shortage of faculty; on the other talented faculty with Ph.D. degree and research publications are suddenly idle after 65 years or at best 70 years of age. For research professors or honorary / distinguished visiting professors; there should be no retirement age like in developed countries in USA, Canada, Australia etc. so long on a professor is physically and mentally capable and is willing to guide research and teach. For faculty the age should never be a bar. This way we help augment faculty resource and avoid wasting talent and wisdom of senior citizens / retired eminent faculty. This strategy will make the difference. This does not require money but just the will to do it.

6. Strategic Roadmap to Enhance Research Output of Technical Institutes

Based on above discussions, the following strategies may help in quantum *jump in* research outputs and outcomes in engineering and technical institutions and universities in the country.

1. Increase, very substantially; the budget allocation for research in the college / technical university. Stop treating research / research scholars as cost centers. Look at research as an investment in talent nurturing, product innovations and brand building of an institute. Globally, educational institutes are known and branded depending upon their research and publication outputs. It is suggested that to start with, at least 10% of annual budget of the college be earmarked to facilitate research.
2. Increase, very substantially, the number of Ph.D. scholars – both full time and part-time to have a 'critical mass' of research scholars on the campus. In the long run, 5-10% of total student population on campus must comprise of the research scholars, 20-30% must comprise of M.Tech students.
3. Enrich the faculty resources substantially to guide research by attracting motivating and retaining the talent. Augment it with outstanding professors / academicians R&D scientists from research labs. Inviting them to become honorary distinguished research professors or emeritus professors or mentors after retirement perhaps on 'life-long' basis. Give them respect; dignity,

mentees to guide and a reasonable honorarium. Pro-actively look for these wise mentors and persuade them to accept mentorship, instead of expecting them to apply. Most importantly, do not treat them as employees but a talent pool of the college to enhance its image and branding.

4. Technical universities must have e-governed processes of research admission, performance review and monitoring of progress and processing of theses examination to compress processing lead time. To attract brilliant scholars to get enrolled in research; a rolling advertisement on website be placed to attract immediately brilliant scholars to enroll for research. Many a times, due to the bureaucracy and processing delays, a potential research student is lost as he/she may either get de-motivated to do research or go elsewhere.

5. Industry must increase significantly, its research budget allocation and offer attractive and inspiring employment opportunities to Ph.D. degree holders in engineering. This would motivate large number of brilliant scholars to pursue research, research topics should also be made available to scholars from industry to reflect on relevant, topical themes rather than working on imaginary or irrelevant topics or extensions of work done in other countries. Industry should sponsor research fellowships of attractive amount (say Rs. 40,000/- per month) for 3-4 years in a technical institute on a topic relevant to R&D to that company and must have a say in the choice of the research scholars. After Ph.D. degree, the candidate could be encouraged or attracted to join in that company as R&D scientist / manager. This collaborative venture will be a win-win proposition to academic as well as industry. Industry should invest 5-6% of its profits on research and development and eventually 2-3% of its annual sales turnover on it.

6. Colleges – particularly star performers must be given autonomy to recruit, mentor, review progress of its research scholars with enabling flexibility in the processing. To ensure quality, benchmark with best practices of international standards of thesis quality with at least two good quality research publications in journals as a pre-requisite before giving degree and mandating one of the thesis examiners to be from a research wise developed world.

7. Invest in e-journals in the library to enable scholars to have real time access to latest journals on the subject. Have ICT enabled knowledge resources and incentives scholars and faculty to publish in reputed journals and present papers in reputed conferences. External research guides from India and abroad who could interact through e-mail or video conferencing will enhance research quality and productivity.

7. Concluding Remarks

In this paper, the author has attempted to highlight the dismal picture of quality and quantity of academic research in engineering and technological institutions. A huge gap between demand and supply of engineering Ph.D. has led to enormous faculty shortage, particularly at the middle and senior levels. A number of strategic interventions are suggested which, if implemented in true earnest, can turnaround the situation. If India has to play a significant role in emerging knowledge economy, it is almost an operating necessity to do so.

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