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ADVANCEMENT OF IE AND SYSTEMS ENGINEERING PRACTICES IN INDIA

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Abstract

Profits, quality, efficiency… No other engineering discipline targets these as fervently as a passionate industrial engineer (IE) does. To do this the IE does not design fighter aircraft or smartphones. He hunts for the right methods, ideas, tools, technology, and human engagement, to profitably deliver products or services by their suppliers, nonstop. As is also true globally, our survey now indicates that by far the largest demand for industrial engineers in India is moving to data analytics, data science, robot applications, AI/ML, and Industry 4.0, from factory-anchored production management. Young IE graduates, being particularly endowed in analytics and advanced computing methods, prefer and are getting rapidly into India's vast software sector, Big Data projects, Analytics applications, AI/ML, and telecom resource deployment.

INDUSTRIAL ENGINEERS ARE TODAY'S "SOFT" ENGINEERS

Note that even if diverse in the careers they enter, being IEs in a rapidly developing land they are all singularly seeking productivity, efficiency, and profits. Systems studies and data acquisition methods remain at their core. The Model T Ford wouldn't roll off in the thousands without the systematic study of the shop methods and tools used, and the prudent deployment of resources. Ford's legacy inspired the invention of the Toyota production system, at the core of which, it is fully recognized, resided industrial engineering. And this motto remains in force today when complex space missions are being simulated in Hyderabad or Bangalore, or frugal engineering laid over value engineering is commissioned to design and launch new peoples' cars in Mumbai—all done with great pride by Indian engineers. Industrialization of India got off in earnest a hundred years back when the Tatas started rolling steel plates and rods in their new plant in Jamshedpur in Eastern India. Soon enough, to become a success the Tata metallurgists, mechanical and electrical engineers could spot that the plant had to deliver productivity and quality, not particularly the forte of their own respective "hard" technology specializations.

At about the same time, Kirloskars set up facilities in South India to produce agricultural pumps and diesel engines to push out British imports, which they did very effectively, in tens of thousands. Their mission was led by a top *manufacturing* engineer, Shantanurao Kirloskar—hands-on—by undoing the prevailing methods and equipment, using elaborate systematic studies of production and distribution practices (Kirloskar 2008). This mantra endures, for a nation's economy, hence its industry, must be competitive and grow. The Indian manufacturer Mahindra Tractors today rolls off shiny agricultural tractors more in number than any other tractor maker in the world (Mohanty and Augustin 2013). Many such achievements are traceable to Indian industrial engineers designing, operating, and perfecting "systems," the knowhow for which is not covered in mechanical, electronic, metallurgical, or in any other branches of engineering specialization. Over 80 engineering colleges and universities in India now offer distinctive full-time IE degrees—a four-year degree, or a master or Ph D. IE graduates can be found now in every sector, including automobile, airport design, healthcare, FMCG supply systems, Big Data analysis, analytics consulting, and coders in Bangalore developing AI/ML-based scanners to diagnose cancer.

CONTRIBUTION OF IE IN THE INDIAN ECONOMY'S GROWTH

Being among the fastest-growing economies in the world, India has tossed up some very unique value creation opportunities for its huge pool of technological talent leaving educational institutions every year. On the demand side a large and growing number of its urban and rural consumers are now aware of global trends and tastes. Varied demography and rising disposable income have fired up consumption. Malls are full. Farmers are briskly buying tractors and mechanizing harvesting and irrigation. Energy management and pollution control are a part of formal lingo in India's boardrooms. Thus growth and boosting up the economy being now the agenda for everyone, the scope of Industrial engineering in India has become immense. IEs form a critical resource among the knowledge engineering community as well, residents in Bangalore, Pune, Gurugram, and Hyderabad playing with AI/ML and Big Data. However, given this, "conventional" IE still thrives in India, as it does in Japan. We list below a sample of the Indian IE's customary contributions—drawn from the grassroots—instances where they are routinely contributing to 25% of the manufacturing and service sectors.

- Walmart formally states, "Delay payments; collect cash from customers immediately!" Their goal here is to generate additional income by managing their *working capital* better. IEs working with a highway petrol station north of Mumbai raised its inventory turnover two-fold, without affecting customer service. This hydrocarbon stock had stashed 75% of their cash without a return. The savings paid off the station's operating expenses at no extra cost—a net gain for the delighted owner.

- A specialized furniture manufacturer in Jaipur had operated with 60-odd workers for a decade without a change in profitability. An IE optimized his product mix—wood and steel chairs, tables, dressers, and shelves—to give him the most profitable weekly production schedule to supply to stores in Delhi, by using Excel's LP Solver. The IE trained the office staff to use this tool. This created spare weekly capacity as well, without stretching the resources.
- A medium-size Indian airport customarily used FIFO to assign landing/take-off slots to aircraft arriving and departing. An IE identified the problem to be multi-objective. She created a template that dynamically compared four dispatch rules—FIFO, shortest runway use, due dates, and random assignments—for given demand scenarios, in minutes, for 10-12 waiting aircraft. This quickly identified the Pareto dominant solutions—every hour—for the ATC to consider.
- An automobile ball bearing manufacturer using conventional technology suffered regular returns and warranty complaints. High variability in part dimension was located as the culprit. However, the plant owner could not see how he could justify the cost of switching to an "expensive" superior machining technology. An IE conducted a Monte Carlo simulation to identify how grinding variability impacted the first pass yield of the quality of the rings made. This quantification led the firm to switch to CNC technology that boosted quality, cut losses, and also gained new business.
- An engineering design firm had developed an elaborate system to generate CAD data for a complex product. However, a lot of effort was required to prepare the data, do bench tests and calculations—for each round producing the CAD data. An IE walked through the steps and created enough training data for a 3-layered neural net (ANN) to relate input to output. Once validated, the new system could be used for a wide range of design variations to support CAD work. These cut weeks of engineering and testing effort to develop prototypes.

Each above illustration comes from an Indian firm with whom the author has been engaged. The older practices came from legacy and ran for months and years with their inbuilt losses or handicap. It is easy to see the difference a knowledgeable IE alone would make here, harnessing a systems perspective and analytics, without pushing "sophistication" for its own sake. Thousands of IEs in India's organized sector are regularly generating such ₹ savings.

EDUCATION AND DEPLOYMENT OF INDUSTRIAL ENGINEERS IN INDIA

It remains indisputable that what comes into a manufacturer in Pune or Chennai or Gurugram Haryana (raw material, subassemblies, labor, etc) to what stays in (inventory) and what goes out (finished goods), everything must be controlled, managed, and optimally treated. From delivery/logistics companies to e-Commerce sites to manufacturing companies to textile to FMCG companies, everyone wishes to operate productively and frugally—to make a profit and expand. Invariably, accomplishing this falls in the lap of IEs, for finally, IEs are scapegoated for high cost and low productivity. Even the others in the plant—in spite of their not being trained as IEs—attempt to do by common sense what it appears that an IE does. Furthermore, the fact remains that even today, due to the abundance of manpower, Indian business processes involve thousands of *human* hands. Few organizations presently justify, for instance, automating warehouses and simultaneously laying off the package handlers, even if most Indian auto plants are fully robotized. Working with such a mix is what IE's expertise is. Hence, a firm operating in a competitive environment cannot stall to best manage with the resources that it has. So it cannot disenfranchise its IEs, even if the IEs are not seen busy designing motorbikes, washing machines, or laptops.

In many organizations, IEs are given the charge of making system-level, tactical and operational decisions. Still, Indian industrial engineers in a firm are responsible primarily for the proper and the most efficient interaction of 4Ms, and new technologies—in *production*. Admittedly, the direct use of IE only to best use manpower in manufacturing is gradually reducing, due to the automation of mass production. Still, in setting up factories in India, or new hospitals, or planning construction projects, as in Japan, India's IEs regularly use standards to guide work-study, time study, and later to plan and manage shop level operations. The engineers use this data subsequently for modeling and simulation, and to optimize system designs and derive cost reduction. Consequently, in college, Indian IE students spend a good first four semesters learning the core IE subjects, computing, humanities, microeconomics, and statistics. The next four semesters are given to learning business management, modeling, and optimization, and electives in Lean Six Sigma, project management, reliability engineering, robotics, and advanced computing, including AI/ML and data analytics (Bajpai and Akhtar 2017). In most Indian universities teaching IE aspirants, such material forms the sizeable part of the 4-year degree program, alongside some electives in conventional engineering specializations, akin to US colleges. See Table 1.

In fact, shortly after independence Indian industry leaders, educators, and the government recognized that to enable big strides to be made by the young nation's economy, its limited technology, and material resources had to be managed and used in the best manner possible. By their nature, such methods are not covered to any meaningful depth in mechanical, electronics, metallurgical or civil engineering. This led to the government's setting up an extraordinarily capable IE teaching and research institution in 1963 at Mumbai, known as the National Institute of Industrial Engineering (NITIE)—described in some detail below. NITIE graduates and diploma holders now number in thousands and have been the hands-on builders of world-class technology-endowed production plants, quality-capable facilities and systems, complex supply chains, and infrastructures, around the country. NITIE's programs and curricula were later on emulated by over eighty institutions nationally. These developments openly illustrate how IEs have been integrated into India's industrialization. Owing to

their forte in quantitative methods and computing, IEs are now entering and enriching the era of knowledge engineering as well. Indeed, many Indian IEs, while working for a large corporation, quickly realize the extent to which powered data analysis and science can impact a business. Since industrial engineering has already given them the foundation (computing, optimization, and statistics) to work in this domain, several are now seen to take extra courses and certifications, to become a data scientist.

INDUSTRIAL AND SYSTEMS ENGINEERING AS A FIELD OF STUDY IN INDIA

If you are an industrial engineer in India, you are treated like a diamond in the human resource market. You are already trained in state-of-art IE subjects and have practiced those hands-on in your capstone project and internship. You would then easily match what the best IEs deliver globally in production, supply chain management, and general management. Note, however, that with the superior facility and aptitude in working with quantitative methods that they have, a fourth of Indian IEs go on to highly esteemed careers in academics as well. Indian professors are found in leading engineering and business schools on every continent. They teach, write books and publish papers, consult, and fervently engage with young IE aspirants.

Let's take a look at the work log of five typical Indian IEs that the author recently sampled. Note the knowledge, a trained mind, and the special skills that each brought with them to their employer.

- An IE in her fifth year of employment in Chandigarh designs better methods and facilities for manufacturing and services. To do this she studies the various industrial processes involved and uses mathematical models and computer simulations to devise new manufacturing systems that are more efficient.
- An IE now in Lucknow played a vital role in setting up of an automobile manufacturing unit. For this purpose, he visited operating plants in Japan and Korea. He was responsible for determining the suitability of locations for major equipment, robots, the transportation system, and in doing this he used simulation to find the best combination of part receipts, material flow, subassemblies, inspection stations, line layout, vehicle movements, dispatches, and costs.
- An IE in Tamil Nadu played the central role in automating the production process. He was responsible for determining what aspects of production needed to be automated and if it made financial sense. He also decided to select the machines which fitted the overall production requirements.
- An IE in Mumbai works for a large multinational consulting firm. His job involves computerization of business processes: big data exploitation, decision support by analytics, OR models in process planning and execution, and product design optimization. The company also does risk analysis and market research. As such, there is no distinction between what this IE does and what his MBA colleague—a pass out from an Indian Institute of Management—does.
- An IE working in Pune was involved in justifying the up-gradation of an existing machining plant producing engineering products. Quality, capacity, and cost of capital equipment were the key considerations. He determined how the alternative solutions affected the size of the firm's profits, its labor relations, as well as production costs. In many ways, he worked as the bridge between management goals and operational performance of the alternatives.
- An IE graduate of SP Jain, Mumbai led a frugal engineering team at Tata Motors to materialize a personal initiative of the Chairman, to be designed as a safe alternative for the Indian families crammed onto scooters. The Chairman's off the cuff estimate for the car's price became a 'stretch target' for the product team. The team started from scratch. It was not only a case of removing unnecessary features (to the extent of providing only one wing mirror and three nuts per wheel) but the car was the product of a web of international supply chains, and probably the most iconic of frugal engineering products to date (Palepu 2011).

Clearly, these jobs are very different from conventional mechanical or electrical engineering jobs. For this, you must possess an aptitude that has a system-oriented mindset, rather than an eagerness to get deep into narrowly specialized knowledge areas, such as VLSI design or computational fluid dynamics. You must also have a genuine interest in closely relating to the *business* side of the enterprise—how does the company earn money? How must it deploy and manage its myriad resources—labor, skills, technology, material, information, and knowledge inputs—to competitively strive for profit? One here must be a problem solver, often when on his feet. His outlook must also be to drive for frugality in every aspect, be it through innovations, people skills, or analysis. A key challenge in India for those producing goods or providing services is to balance the needs of the large pool of human resources available, market trends, and the potential of technology.

To be effective, and importantly relevant to the needs of industry, therefore, the training and development of IEs in India are *not* made laptop-focused. Rather, it pushes applications with the aim to impact shop practice, for that's where the majority will be employed, with a small fraction going for a Ph D (Nrraokc_blog 2020). This bears on the curricula in place in IE colleges. Being PMI certified or being a Six Sigma Black Belt is also popular among IEs. We outline below a typical program that NITIE uses. A big component of it is a large hands-on internship. The other is to keep the training close to the practice of business management.

A related interdisciplinary field of study is systems engineering, which focuses on the design, integration, and management of complex systems over their life cycles. Systems engineering uses systems thinking principles—an approach that focuses on the way that a system's constituent parts interrelate and how systems work over time—to accomplish this. However, as is true in many countries, undergraduate formal degree programs dedicated wholly to systems engineering in India are only a few,

though over thirty colleges conduct master and doctoral programs in systems engineering. This program is interdisciplinary. In it they draw resources from IE, process systems, mechanical, manufacturing, control, software, electrical, and aerospace engineering, cybernetics, organizational studies, and project management. Leading institutions among these are the IITs, IISC, and BHU with their high-quality facilities. The Industrial and Systems Engineering program conducted by IIT Kharagpur is a revered one. As of writing, most engineering firms in India, ISRO, defense development labs, and engineering and software design companies are the regular users of systems engineering.

NITIE—INDIA'S BEST UNIVERSITY OFFERING INDUSTRIAL ENGINEERING

NITIE (National Institute of Industrial Engineering), located in Mumbai, offers industrial engineering and management education to students. It offers four postgraduate courses named Post Graduate Diploma in Industrial Engineering (PGDIE), Post Graduate Diploma in Industrial Management (PGDIM), Post Graduate Diploma in Project Management (PGDPM), and Post Graduate Diploma in Industrial Safety and Environmental Management (PGDSEM), respectively. It also offers Doctoral Fellowship programs in Decision Sciences and IT Systems, Organizational Behavior and Human Resource Management, Manufacturing and Systems Management, Project Management, and Industrial Engineering. Summer industry internship is an integral part of every NITIE program. However, NITIE *does not teach* production technologies, an area covered intensely by the Indian Institutes of Technology (IIT), the National Institutes of Technology (NIT), and numerous others. Furthermore, NITIE's programs are only for engineers and the majority would enter NITIE after having two to three years' work experience in industry.

Additionally, every year, NITIE trains over 2000 working professionals through its various week-long Management Development Programs (MDPs) and the Unit-Based Programs (UBPs) in different areas of industrial engineering and business management. Since its inception, NITIE has been at the forefront in creating industry-ready professionals who enter industry sectors that span Consulting, Manufacturing, and Distribution, FMCG, Software, Financial Markets, and Telecommunications. Regarded to be the *Mecca* of Supply Chain and Operations Management in India, NITIE commands 100% placement. It is claimed credibly that there isn't an industry operating in Pune, Mumbai, or Chennai—the large scale manufacturing hubs of India—that does not have a NITIE graduate on its roll. The captivating location in the cradle of Mumbai's Vihar and Powai lakes have also made their surroundings envy of most among India's teaching institutions. In 2020 NITIE graduates left its portal with job offers in the top 10% of Indian engineering salaries ranging between two million and 6 million rupees per year. A blog on the global practices of IE prepared by the NITIE's IE faculty appears at (Nrraokc_blog 2020).

NITIE's postgraduate curriculum has been designed and continuously restructured to develop a strong conceptual, fundamental, and analytical reasoning ability, along with the skills needed of a manager. I indicate here only the contents of PGDIE (postgraduate diploma in industrial engineering program), as this Handbook is focused on IE. Many Indian engineering colleges have emulated NITIE's IE syllabi.

The contents of PGDIE cover the objectives and challenges of managing efficiency and productivity in different functions of production and service organizations. The subjects include Manufacturing Management, Operations Management, Ergonomics, Supply Chain Management, Statistics, Project Management, IT, AI/ML and Big Data techniques, Marketing Management, Finance, and Human Resources Management. The program now includes the concepts of the fourth industrial revolution, Industry 4.0. The pedagogy borrows best pedagogic practices from the IITs and IIMs, such as developing case studies, role plays, projects, computer-aided instructions, online instruction, group discussions, lectures, seminars, along with presentations and guidance provided by domain experts and IE practitioners from industries.

Many NITIE students are given a chance to taste entrepreneurship first hand. They are given two thousand rupees on a weekend to go and set up a "business" of their choice somewhere in the city of Mumbai to peddle a product or service, hawk all day, and then return in the evening—to compare notes. Thus, NITIE targets all-round development, preparing students to take up diverse responsibilities in manufacturing and service environments and for consulting in production, distribution, FMCG, software engineering, financial engineering, and Telecommunications management jobs, to name some. It is with much pride that this institute's faculty asserts its capability to produce top rated IE hands and brains—to impact and manage the drivers of India's growth.

SPECIFIC INSTANCES WHERE AN INDIAN IE MADE A MATERIAL IMPACT

- Project management – IRSO's space mission activities, developing and launching new vehicles, technology management; a new algorithm created to schedule LEO spacecraft task support at 25% cost quoted by a foreign firm
- Product development and their commercialization – Aircraft (HAL), armaments and the ordinance, R&D for defense organizations (DRDO), motor vehicle design and manufacture (Mahindras, Tata, TVS, Toyota, Honda), ocean liners, railways coaches and engines; value engineering of construction and mining equipment
- Production planning and production management – productivity and cost reduction awareness building by forming industry clusters (NPC); Industry 4.0 training (IIT)
- Quality assurance and management, proprietary robust design of electronic devices (none except IEs could do this!); numerous Lean Six Sigma and Kaizen projects
- Supply chain management and ERP implementation – production, handling, and distribution of fast-moving consumer goods to urban and rural markets (HUL, ITC); fertilizer production and distribution (Coromandel, Tata Chemicals); improved customer service to state-of-art level

to enable effective digital commerce (Amazon, Flipcart, Snapdeal)

- Setting up factories - Steel mills, the auto sector, refineries, and chemical plants
- Infrastructure development – roads, irrigation, transportation, ports and airports, hospitals, telecom
- Frugal engineering – Tata Nano, a $2000 passenger vehicle (Girish Wagh, an IE, led the project from concept to production); ISRO's Mangalyan mission planning and execution – delivered at *one-tenth* cost of comparable missions elsewhere

EDUCATING INDUSTRIAL ENGINEERS IN INDIA

Let's look at the drivers for the shift emerging in India in training IEs. As noted, over eighty universities and institutes in India currently run one or more full-time formal degree programs in IE. The admission for the 4-year degree (B Tech) is through national and state level competitive entrance examinations given to 10+2 graduates of India's school system. The aspirants invariably are physics, chemistry and math students. About 5000 individuals graduate in industrial engineering in India every year.

Many colleges run separate 4-year degree programs in *production and industrial engineering*, generally for industry engaged in manufacturing. Production engineering, also known as Manufacturing Engineering, deals with planning, designing, developing and managing of various processes to produce high-quality products. Indeed there is a huge body of Indian businesses whose primary focus is production. Hence production engineering is taught by the department of mechanical engineering in many colleges. Such a program has significant overlap with IE programs, while it has a good infusion of modern manufacturing methods and technology.

It is pertinent to spend a minute to point out the "difference" between industrial engineering (IE) and production engineering (PE). Naivety often overlooks this, but the difference mainly is in our expectations of the graduates of the two streams. The domain from where problems and challenges would come to production engineering is the factory, the plant, or the facility whose primary function is to convert the inputs (manpower, machines, materials, methods, information, and technology) into finished goods. The methods and tools a PE uses include not only those that let the production system function efficiently and profitably to deliver quality goods but also the particular *conversion methods* being employed. Because he gets close to machines and "machining", the subjects the PE studies would typically include theory of machines, heat transfer, metal cutting and tool design, material science, CAD/CAM, etc., including advanced manufacturing methods and technologies. By contrast, the domain of IE is much broader. IEs serve not only factories—doing much of what the PE does—but being much more interdisciplinary in their orientation, they can also contribute to the proper functioning of a hospital, a transport system, a construction project as a resource manager, a Six Sigma project, or anywhere the non-manufacturing enterprise seeks profits, quality and efficiency. IE training now includes project management, systems engineering, advanced data science, analytics including a good dose of modeling and optimization, and AI/ML. However, recall that the basic subjects that both PEs and IEs study and the knowledge that they are imparted have an identical and singular objective—to seek profits, efficiency and quality in the systems they will be dealing with. Both streams thus must include a good deal of basic industrial engineering, methods and time studies, statistics, OR, industrial management, and state-of-art computer programming.

Thus Indian PEs and IEs can substitute for each other a great deal, with some additional training. This is generally not easy for someone who specialized in mechanical engineering, electronics, metallurgy, or computer science; such specialized engineers often miss a lot of profit and efficiency improvement opportunities in their initial years in industry. Many large Indian universities, therefore, allow their "engineering" students to study electives in non-technical domains also to broaden their background and raise their employability. One popular domain is business management. Another is knowledge engineering. A third is financial engineering.

For a two-year masters degree (M Tech) in IE, the applicant must be an engineer of any specialization, but must qualify in the nationally administered GATE (Graduate Aptitude Test in Engineering) test. Those aspiring for a Ph D must have a deep interest in research and independent studies, and a master's degree. Most M Tech and Ph D students are financially supported by the Indian government to offset their opportunity cost.

Expanding well beyond math models of OR, today India's IE course curricula, projects, and even research have now become *demand-driven*. The increasing complexity of industrial operations and the expansion of automated processes in Indian factories and offices are pushing for hiring the new breed of industrial engineers. Every few years, well-oiled production lines, technology, decision support systems, and product and process designs are being ripped out and replaced—to outdo competition. College curricula therefore must get continually upgraded. This is what the author now hears from directors, deans, faculty, alumni, and even students, who must assert to be an imperative asset for his employer. To infuse new blood, the strategy that Indian schools teaching IE employ is to hire fresh Ph Ds in IE, OR/OM, data science, supply chain, AI/ML, Robotics, etc. from top universities, and frequently bring in practitioners and business executives into the classroom. Course contents and programs reflect this continual change in most IE programs. It is quite common now to also see an Indian instructor look up what IEs are learning in Georgia Tech, Texas A&M or Tokyo.

ACADEMIC PROGRAMS IN INDUSTRIAL ENGINEERING IN INDIA

To meet the incessantly evolving demands of industry and society at large, since 1960 the discipline of industrial engineering itself has acquired a variety of shapes. The representative curriculum of the Indian IE undergraduate program therefore reflects a mix of traditional IE and what is emergent. This is indicated by the streams and courses listed in Table 1. What is more, many institutions have seen the high value of *applications* discussed in the class next to theory. They have adopted Outcome Based Education (OBE), a pedagogy that directly aims on impacting the existent practices and processes. It encourages proactive commitment of creativity and innovation on the opportunities.

Representative areas of postgraduate Research / Consulting / Project Work in IE include Lean, Green and Agile Manufacturing; Applied Ergonomics; Supply chain and Logistics Management; Energy Management; Service Sciences; Performance of Retail Sectors; Performance of Health Care Companies; Automation Science and Technology; Learning Organizations; Business Excellence Models; e-Governance; e-Commerce; Modeling Intelligent systems; Agriculture Supply Chain Networks; Six Sigma Manufacturing applications in Manufacturing and service industries; Data Analytics using data warehousing and data mining tools; Social Network Analysis; Infrastructure Management; Business Intelligence models; Technology innovation; Any other areas contributing to the productivity, cost, time, quality, customer satisfaction, business excellence, enhancing competitiveness.

Institutions offering IE programs in India number about 80. Among the reputed institutions offering UG/PG degrees are IIT Delhi / Kharagpur / Bombay / Kanpur / Roorkee, Anna University, BITS Pilani, NIT Trichy / Calicut, Jadhavpur University, Chandigarh University, Thapar Institute of Engineering and Technology**,** NITIE, VNIT Nagpur, Delhi Technical University, PSGCT Coimbatore, Colleges under VTU, Karnataka (RV College of Engineering, Bengaluru / BMS College of Engineering, Bengaluru / RIT, Bengaluru / SIT, Tumkur / BIT, Bengaluru / DSCE, Bengaluru). Eighty odd universities conduct formal full-time 4-year IE degree programs. Together, as stated, they graduate 5000 industrial engineers annually.

INDUSTRIAL ENGINEERING TOMORROW!

Current recruiters tell that the skills expected of an IE by Indian firms still are production, project management, AutoCAD, Kaizen, 5s, Six Sigma, intellectual property, maintenance, supply chain management, logistics, B2B / B2C solutions, and TPM. A job opening for an IE is still stated as "Production Engineer wanted," or "Quality Engineer wanted." Thus for the next decade, like manufacturers all over the world (Nrraokc_ blog 2020), many Indian firms will still look out for IEs who can provide tidy, systematic and innovative ways to obtain quality, cost reduction and efficiency. However, now you will see many ads asking for IEs to handle business and data analytics, AI/ML, and Big Data and e-commerce systems. New tools to deliver these demands are rapidly entering the IE's training. A fast emerging area where many Indian IEs and college programs are already moving to is *knowledge engineering*.

These youngsters are now tweeting the booming AI/ML and data science markets. This preference seems natural, given the in-depth training that IEs receive in analytics, optimization, statistics, state-of-art computing, business management subjects, systems thinking, and soft skills. Other professionals, it is clear from the media, are also trying to catch up with this wagon through certifications and short courses, as demand is fast rising. However, the author expects that many well-endowed IEs will soon shift away from the conventional complexion of industrial engineering to this. India's customary dependence on muscle-driven skills in mass production is fast-moving to automation. Effort is afoot now to exploit this very germane domain. As of this writing, knowledge engineering and data science have already shown a vast potential to positively impact decisions and challenges, well beyond those in the factory. Indian IEs, this author projects, will be strong sluggers on this field.

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REFERENCES

1. *Bajpai, S and S Akhtar (2017). Industrial Engineering Education in India, DOI: 10.1515/rpp-2017-0040, License CC BY-NC-ND 4.0, Project: Engineering Education In India January.*
2. *Kirloskar, S L (2008). Cactus & Roses—An Autobiography, McMillan India Limited.*
3. *Mohanty, Rajendra Prasad, Prince Augustin (2013). Business strategy of automotive and farm equipment sector of the Mahindra & Mahindra Group of India, JSMA, 7(1), www.emeraldinsight.com/1755-425X.htm*
4. *Nrraokc_blog (2020). Industrial Engineering Knowledge Center http://nraoiekc.blogspot.com/2020/03/industrial-engineering-in-top-global.html*
5. *Palepu, Krishna G, Bharat N Anand and Rachna Tahilyani (2011). Tata Nano The People's Car, Harvard Business School Case 710-420, April 2010. (Revised March 2011).*

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Table 1. Representative Curriculum of the Indian IE Undergraduate Program

Basic Mechanical Engineering and Manufacturing Sciences	Applied Mathematics, Applied Physics, Elements of civil Engineering, Computer Aided Engineering Drawing, Elements of Electrical Engineering, Applied Chemistry, Computer programming Language, Elements of Electronic Engineering, Elements of Mechanical Engineering, Material Science & Metallurgy, Mechanics of Materials, Machine Design and Drawing, Fundamentals of Mechanisms and Energy Systems, Tool Design, Hydraulics and Pneumatics, Industry 4.0 – A Growth in Manufacturing, Additive Manufacturing Methods, Digital Manufacturing,
Industrial Engineering	**Design of Work Systems,** Measurement & Metrology, Manufacturing Process, **Applied Ergonomics,** Statistical Quality Control, Operations Management, Computer Integrated Manufacturing, Facilities Planning & Design, Supply Chain Management, Modern Manufacturing Methods, Robotics, Rapid Prototyping and Manufacturing, Just in Time Methodology, Lean Manufacturing Systems, Services Operations Management, Innovation and Value Engineering, Retail Supply Chain Management, Supply Chain Technologies,
Quantitative Models including Business Analytics	Business Analytics, Data Science, Decision Science, Operations Research, Simulation Modeling & Analysis, Design of Experiments, Reliability Engineering, Engineering Economy & Financial Accounting and Costing, Entrepreneurship development, Engineering Optimization, Multi Criteria Decision Modeling, Meta Heuristics including Machine Learning & Artificial Intelligence and Soft Computing.
Humanities and Social Sciences including Liberal Education	Regional and Foreign Languages, Constitution of India and Professional Ethics, Environmental Technology, Principles of Management, Entrepreneurship and Intellectual Property Rights, Project Planning & Control, Marketing Management, Human Resource Management, Management practices for Business Excellence, Total Quality Management, Technology Management, Energy Management, Managerial Economics, Studies of Various sectors of economy, Liberal Education
Information System Design	Management Information Systems, Product Life Cycle Management, Internet of Things, Cyber Physical Systems, Digital Technologies, ERP/SCM/CRM/B2B/B2C, Cyber Security, Internet of Things, Cyber Physical Systems.
Skill Based Labs and Experiential Learning	Labs in Mechanical Engineering, Production and Industrial Engineering, Decision making and Information system streams, **Technical Seminar, Minor project, Project Work, Experiential Learning includes Design Thinking Lab, Applied Psychology Lab, Project based / Problem based solutions – course wise and other innovative practices conducted offline and online.**