# Engineering Training for the Data Driven Economy: A Historical Analysis

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## Introduction

It is not difficult to prove that Engineering, Engineering Practice and Curriculum are products of technological advances in general. This fact immediately tells us that failure in development or technological advancement is also a failure in practice and failure in what is taught. There is a close connection between a nation's Economy and its Engineering. When one is doing poorly, the other probably is not doing better either. We link the latter, naturally to curriculum. To gain a historical perspective into any serious discussion on national development in a technological sense, we will first need to look at the courses that converged as the 19$^{th}$ Century turned into the 20$^{th}$. As we shall recall these events were germinating in fertile minds in the 19$^{th}$ and earlier centuries; the bountiful harvest of this convergence was what defined the last century – to which most of us actually belong! We will proceed further into the paradigm shifts we are witnessing today and connect it to the response we ought to provide in the preparation of our Engineers for tomorrow's industry.

## Converging Courses

**1. The End of the Horse Era**

"*In 1898, delegates from across the globe gathered in Ney York City for the world's first international urban planning conference. One topic dominated the discussion. It was not housing, land use, economic development, or infrastructure. The delegates were driven to desperation by horse manure."(*Morris). The increasing use of horses for transportation on a large scale had generated "*Filth, Flies and Fatalities*" on an unprecedented and appalling rate - Some highlights:

- 3-4 million pounds of manure had to be cleared each day; 40,000 gallons of urine had to be disposed of each day
- 15,000 dead horses had to be carted off each year
- Fatalities from horses were 75 higher than today's fatality rate for autos.

What saved American cities from this environmental disaster? The motor car.

"*As difficult as it may be to believe for the modern observer*," Morris writes, "*at the time the private automobile was widely hailed as an environmental saviour*." In addition, the broad use of the automobile allowed humans to significantly reduce their footprint on the earth as thousands of acres of land were no longer necessary to grow hay, oats, and other feed.

**2. The Internal Combustion Engine**

*An internal combustion engine is any engine that operates by burning its fuel inside the engine. In contrast, for example to, a steam engine burns its fuel outside the engine. The most common internal combustion engine type is gasoline powered. Others include those fueled by diesel, hydrogen, methane, propane, etc.*" The above conference took place at the time when the IC powered cars were being turned into viable commercial alternatives to Animal – powered transportation. The illustrious history of this dominant technology has the following highlights:

(About.com)

•1680 - Dutch physicist, Christian Huygens designed (but never built) an internal combustion engine that was to be fuelled with gunpowder.

•1885 - Gottlieb Daimler invented what is often recognized as the prototype of the modern gas engine - with a vertical cylinder, and with gasoline injected through a carburetor (patented in 1887). Daimler first built a two-wheeled vehicle the "Reitwagen" (Riding Carriage) with this engine and a year later built the world's first four-wheeled motor vehicle.

•1886 - On January 29, Karl Benz received the first patent (DRP No. 37435) for a gas-fueled car.

•1889 - Daimler built an improved four-stroke engine with mushroom-shaped valves and two Vslant cylinders.

3. **Commercial Air Travel**

   The history of air travel began with the flight of the Wright brothers on December 17, 1903. Their plane was a powered and controlled aircraft whereas previous attempts to fly used gliders that had control and no power or free flight which had power but no control.

4. **Amalgamation of Nigeria** (Wikipedia)

   1880 The conquest of Southern Nigeria by the British began.

   1900-etc The Sokoto Caliphate was established through jihad.

   The Sokoto Caliphate went to war against the Yoruba states. Christian missionary activity began in Southern Nigeria.

5. **The European War** Decade 2 of the 20th Century.

   Alias First World War. The Europeans, as they had always done, started quarrelling again among themselves and they called it the First World war. They used this to test all the technological convergencies – a practice that was continued in the intervening period when they were ready to go for the test again in the second world war!

I hope the technological development is not lost in the historical canvas upon which it is painted. These convergences – or paradigm shifts, if you like created the winners and losers. I have argued in a previous paper that each technological shift makes winners of the active participants and losers out of bystanders and onlookers. If we were to go several centuries back, we will observe that our forebears were losers during the age of the explorers like Mungo Park and David Livingstone. The active participants at that time were the Iberian Powers who sent Columbus, Magellan etc to open up trade routes and seize any lands they could; Sign one-sided “protection” treaties, etc. They owned the compass and the Navigational Skills that made them to Master the oceans. To our forebears belonged the gin, the looking glass and free accommodation in the packed vessels that took them with padlocked mouths to go and make sugarcanes for the “Masters”. Does it surprise you that a small nation like Portugal can be allowed to carve out about half of South America for itself? That King Leopold of Belgium actually “owned” what is now Zaire – “stock, lock and barrel” - with its peoples as his personal estate? All are the spoils of the Convergence. Losers are not in for a picnic! They pay, really pay!

We were also losers in the aftermath of the Industrial Revolution that created the thirst for “Raw Materials” for the resource-hungry factories of Europe. Long before Crude Oil, they have been cheating us by taking palm oils and timbers from here while returning inferior products in exchange. It is to our shame that the rail lines, created in the 19th century to bring resources to the ports of Lagos and Port Harcourt for exporting, again, under unequal terms, remain the essential state of development of our rail transport today! This happened after we had made trillion dollars from oil money! O when will our own Rawlings come to clean this mess!

Back to our point: What is the relationship of Engineering curriculum to all this? The best way to answer the question is to examine what engineers were taught in the schools that had engineering schools in the 19th century.

It is worthy of note that the oldest electrical engineering degree program in the world happened close to the turn of the 20th century. "*In 1883, **Darmstadt University of Technology** and **Cornell University** introduced the world's first bachelor's degree courses of study in electrical engineering, and in 1885 the **University College London** founded the first chair of electrical engineering in Great Britain. The **University of Missouri** established the first department of electrical engineering in the United States in 1886.*"

The question then is this: "What engineering programs existed; what were they teaching?"

The History of Engineering has been divided into four major periods delineated by major paradigm shifts:

"*The history of engineering can be roughly divided into four overlapping phases, each marked by a revolution:*

- ***Pre-scientific revolution**: The prehistory of modern engineering features ancient master builders and Renaissance engineers such as Leonardo da Vinci.*
- ***Industrial revolution**: From the eighteenth through early nineteenth century, civil and mechanical engineers changed from practical artists to scientific professionals.*
- ***Second industrial revolution**: In the century before World War II, chemical, electrical, and other science-based engineering branches developed electricity, telecommunications, cars, airplanes, and mass production. The second industrial revolution, symbolized by the advent of electricity and mass production, was driven by many branches of engineering. Chemical and electrical engineering developed in close collaboration with chemistry and physics and played vital roles in the rise of chemical, electrical, and telecommunication industries. Marine engineers tamed the peril of ocean exploration. Aeronautic engineers turned the ancient dream of flight into a travel convenience for ordinary people. Control engineers accelerated the pace of automation. Industrial engineers designed and managed mass production and distribution systems. College engineering curricula were well established and graduate schools appeared. Workshops turned into to laboratories, tinkering became industrial research, and individual inventions were organized into systematic innovations.*
- ***Information revolution**: As engineering science matured after the war, microelectronics, computers, and telecommunications jointly produced information technology*."

If we look at Engineering as defined by the first Industrial Revolution, *"Before that time, the economy was primarily agricultural, transportation was poor, and manufacturing was carried on in the labourers' homes. The invention of the spinning jenny (1763), the water-powered spinning machine (1771), and other mechanical devices gave rise to the factory system and created a need for mechanical power. … The new devices, in turn, required more efficient use of fuels, and more emphasis on factory planning; thus, mechanical engineering was established. Those civil engineers concerned with machines were called mechanical engineers, and as new sciences and skills developed, they became specialists in the new art."*

We can see that while civil engineering came before the Industrial revolution I, Mechanical was a direct result of the revolution itself. Electrical and Chemical Engineering, as we have seen are results of the second revolution. The emerging trends did not leave even the traditional civil engineering itself static. Initially, dynamics in all its ramifications were considered the province of Mechanical engineering. This was to change after the catastrophic collapses of "civil" structures such as the well know debacle of the Tacoma-Narrows Bridge in the US State of Washington. *"The 1940 Tacoma Narrows Bridge was the first Tacoma Narrows Bridge, a suspension bridge in the U.S. state of Washington that spanned the Tacoma Narrows strait of Puget Sound between Tacoma and the Kitsap Peninsula. It opened to traffic on July 1, 1940, and dramatically collapsed into Puget Sound on November 7 of the same year. At the time of its construction (and its destruction), the bridge was the third longest suspension bridge in the world in terms of main span length, behind the Golden Gate Bridge and the George Washington Bridge."*

This tragedy and its aftermath had a profound effect on the development of bridge construction and structural dynamics: *"The bridge's spectacular destruction is often used as an object lesson in the necessity to consider both* **aerodynamics** *and* **resonance effects** *in civil and structural engineering. Billah and Scanlan (1991 reported that in fact, many physics textbooks (for example Resnick et al.[16] and Tipler et al.[17]) wrongly explain that the cause of the failure of the Tacoma Narrows bridge was externally forced mechanical resonance. Resonance is the tendency of a system to oscillate at larger amplitudes at certain frequencies, known as the system's natural frequencies. At these frequencies, even relatively small periodic driving forces can produce large amplitude vibrations, because the system stores energy. For example, a child using a swing realizes that if the pushes are properly timed, the swing can move with a very large amplitude. The driving force, in this case the child pushing the swing, exactly replenishes the energy that the system loses if its frequency equals the natural frequency of the system… In the case of the Tacoma Narrows Bridge, this appears not to have been the cause of the catastrophic damage. According to Professor Frederick Burt Farquharson, an engineering professor at the University of Washington and one of the main researchers into the cause of the bridge collapse, the wind was steady at 42 miles per hour (68 km/h) and the frequency of the destructive mode was 12 cycles/minute (0.2 Hz).[18] This frequency was neither a natural mode of the isolated structure nor the frequency of blunt-body vortex shedding of the bridge at that wind speed (which was approximately 1 Hz). It can be concluded therefore that the vortex shedding was not the cause of the bridge collapse. The event can be understood only while considering the coupled aerodynamic and structural system that requires rigorous mathematical analysis to reveal all the degrees of freedom of the particular structure and the set of design loads imposed."*

One effect is that this, and similar other examples instructed the emphasis on dynamics for Civil engineering structural analyses.

From the foregoing, we can see clearly that the definition of what engineering or its degree curricula may be is not cast in stone. It influences and it is greatly influenced by the paradigm shifts of technological development. It was the prevailing technologies that extended engineering from the traditional field of civil engineering to the mechanical section of the profession. It was again the discovery and utilization of electricity and large industrial processes that created and defined electrical and chemical engineering. The advances in air travel and war making with the mastery of ocean exploration gave us marine and aeronautical engineering. The list goes on.

We can also see how disastrous events can redefine the focus on ancient arts and imbue them with now vigour and scope. Structural dynamics is, today, considered an integral part of civil engineering – it was not so at the earlier times.

## Today Convergence

**1. Adapt or Die**

While we may understand in general terms that failure to actively participate in technological paradigm shifts lead to monumental losses from the national perspective, another view of such losses in a sectoral perspective, even within an industrialized nation can teach us one or two things. The story of one of the largest industrial bankruptcies is an interesting one:

The Smith Corona company originated in 1886 when the Smith Premier Typewriter Company, established by Lyman, Wilbert, Monroe and Hurlburt Smith, created the first machine to use both uppercase and lowercase letters. In 1893, it joined the Union Typewriter Company, a trust in Syracuse, New York which included rival firms Remington, Caligraph, Densmore and Yost….Smith Corona was created when L. C. Smith & Bros. united with Corona Typewriter in 1926, with L. C. Smith & Bros. making office typewriters and Corona Typewriter making portables. During World War II, Smith Corona made Springfield rifles and other small arms for U.S. armed forces. After the war, the company concentrated on making its typewriters more convenient and efficient for use in business offices. Typewriter sales peaked after World War II; in response to a demand for typewriters capable of faster output, Smith Corona introduced electric typewriters in 1955. Electric portables, intended for travelling writers and businesspeople, but later widely purchased for general home use, were introduced in 1957. The new portable electric typewriters would become an essential tool for generations of U.S. high school and college students

The calculator market was devastated by cheap electronic pocket calculators in the mid 1970s. By 1985, personal computers were being widely used for word processing,…,the company announced in 1995 it was cutting 750 jobs as a result of continuing sales declines, and shortly thereafter, declared bankruptcy.

This is one of the casualties of the Information Revolution! At the very same time this happened, the Japanese Epson company transformed itself from a typewriter company to a computer company to the extent that today, very few people remember that the name Epson came from E. P. and sons meaning Electric Printer!

2. **Endgame for the Internal Combustion Engine, Fossil Fuels**? More efficient transportation Systems?

These early years of the 21$^{st}$ century is a time of converging courses. Just like the Horses before them, the internal combustion engines and their prime incarnation as the motor car is today's evil polluter. Its again back to the three Fs: Filth Flies and Fatalities. A visitor from outer space, upon looking at our modern cities may not quickly realize that human beings hold the sway on this planet! It appears that the cities are created to make way for cars other internal combustion engines! We may not be able to put them boxed neatly in the three Fs, yet we can easily see that, over the years, the Filth has exacerbated into environmental pollution on a large scale leading to global warming and the depletion of the Ozone cover for the entire planet. This has raised the problem to another level. The flies are still there in their nuisance value and threats they pose to our wellbeing. They are now in the form of acoustic pollution that make urban life less bearable. As for the fatalities, they perhaps remain at their historical levels.

These are the challenges that are probable prompting the next paradigm shift. The problems of living in the 21$^{st}$ century is primarily a problem in the Energy sector. The Internal Combustion engine with its dependence, directly or indirectly, on wasting energy sources like fossil fuels and the increase in the carbon pollution of the environment may be on its way out or will have to become far more efficient than previously. Transportation, the most important consumer of this resource will have to be redefined. Questions such as why, in the first instance must a single person be moving about in a transport vehicle that is capable of carrying an elephant? Why log so much weight about when all you really want is to get from point A to B? (Of course in Nigeria, we prefer to buy the cars that are bigger, bullet proof, and get several of them on the road at once – chasing all other users off the road! The necessity of making the roads better and user friendly is put in abeyance. This pathological case will require another paper!)

Furthermore, it is a well-known fact that the sheer amount of Solar Insolation we get is still far greater than the energy we can consume. The collection problem in all its ramifications is a matter of serious research and development. This has created a situation such that the cost of solar collectors and PVs is at least halving each year. It has not yet reached the tipping point as solar power still remains one of the most expensive energy system at the acquisition stage. The Jury is not yet out on this pursuit.

Other renewables such as wind, biomass and other biological systems, ocean waves even direct harvesting of the destructive cyclones and lightning are areas that will be pursued as the enormous energies in these systems, if harvested can add to the energy mix. The fact that that the time count on the day the world will run out of fossil fuels has already begun. There is nowhere to go but that we must get a paradigm shift again in the area of energy, In the area of transportation on land sea and air. It is already being suggested that individual aviation modules may be the solution to human transport. This will create enormous traffic control issues that will attract the best of minds. The fact they are individual does not mean that each one will have absolute say in the way they are controlled. After all, we all have private phones that are controlled for us by other people and systems. There is no reason why we cannot all fly about with the control system monitoring collision avoidance, etc on the same kind of scale that our mobile phone access with its collision of calls, etc are monitored and achieved.

In recent times, the turbulence in the Financial sector and failures of housing markets in several countries have led to the use of the chaos theory and theories of turbulence that have been well established in fliud flow. There is such a convergence in the scientific disciplines of engineering and the financial world that new engineering curricula and programs are being minted to cater for these developments.

Mechatronics Engineering started over thirty years ago in Europe and is now gaining currency all over the world. Systems engineering and Design as well as Robotics and Artificial Intelligence are being pursued by engineers. AI is interestingly popping up in so many disparate fields from Linguistics to Mechanical and electrical engineering and Finance and Operations Research that it gets difficult to really know which discipline an AI professional comes from!

Engineering curricular are now taking cognisance of the extension of traditional reaches of engineering to biological systems. Increasingly, we are getting to see more Biological Engineering programs in the universities these days. Biomechanics have been there for a while and the application of mechanics to biological systems are maturing. The initial problems came from the fact that the application of traditional theories fail on two grounds. Often Biological tissues are soft and are therefore subject to large deformations compared with the original states. That immediately implies that the small scale deformation assumptions that have been responsible for the built environment over the past 150 years will not often work. This geometric nonlinearity is coupled with the material nonlinearity inherent in the fact that the Hookean dream of the extension being linearly related to the applied force becomes a pipe-dream indeed. Obviously, this complicates the matter and for many years, serious biomechanical analyses were quite difficult and no closed form solutions could be found for any but the simplest problems. Again, the convergence of IT and the increasing processing power of computers and the ascendancy of structured numerical procedures have made it possible to bring biomechanical applications to the main stream. Close forms you still may not get, but usable solutions to problems in the area of arterial aneurism, cardiovascular implantations and lung cavity analysis are becoming some of the most fruitful areas of mechanics today!

You probably remembered a time when Math, Math Physics was all you needed to get into engineering. Those days are gone! Today, you must add Chemistry to your Math and physics and you will very soon be needing to add your Biology!

A PhD student of mine at the University of Lagos is presently analysing the fatigue strength of cured tooth implants to understand their mastication resistance and long term strength in order to understand how to make more durable ones. We have obtained the constitutive behaviour at uniaxial loadings already. In this work, we are beginning to collaborate with the Faculty of Dental Sciences on this issue.

## Technology Paradigm Shift

### Japan: Competition&War

A proud ancient people of a world regarding empire-building nation, the Japanese were latecomers into Automobile technology. It was the American Detroit-based auto giants that first saw in Japan a big market for the expansion of their trade. The Japanese as empire and a warrior imperialistic nation in its own right never had too much patience in being a sitting duck and a trading post for foreign concerns. The need to acquire the technology was in the Japanese mindset from the very beginning of the US automobile "Invasion". The sense of purpose and clear focus in acquisition of automobile technology was the key in Japan's success. 1914, Mitsubishi Zosen manufactured 22 Mitsubishi Model As, the first mass production cars in Japan. 1918, the Military Vehicle Subsidy Law was established. Under this law, the military granted subsidies to automobile manufacturers to produce vehicles (mostly trucks) to be used by civilians during peaceful times and converted to military use in times of war. This was in effect Japan's first automobile industry policy.

The recent disaster is not the first time the Japanese Islands have suffered setbacks due to a major earthquake. Around 1927 when the Japanese where grappling with the after effects of an earthquake similar to the recent one, foreign motor manufactures were breaking into the Japanese market. In February 1925 Ford established Ford Motors Japan in Yokohama Japan and began local assembly and sales (in June of that year) of Model Ts. GM followed suit; establishing GM Japan in January 1927 and commencing local assembly and sales of Chevrolets in April.

The occupation of Manchuria (northern China) by the Japanese military in 1931 exacerbated already difficult relations with the West. The basis for war grew steadily stronger, and in 1936 the Japanese Ministry of Commerce and Industry and the Ministry of War jointly supported the establishment of the Automobile Manufacturing Industries Act. The aim of this legislation was ostensibly to stifle the monopolization of the automobile market by American manufacturers by fostering domestic mass production of motor vehicles to meet the needs of the public. An additional goal was to ensure the uninterrupted supply of vehicles for the military. Between 1925 and 1935, the General Motors, Ford and Chrysler produced a cumulative total of 208,967 units in Japan. In contrast, domestic production for the same period totalled 12,127 units, just 5.8% of what the American's had produced! After 20 years of effort, the Japanese could only get 5.8% of their own market due to overbearing foreign competition offering better products at lower prices: Cars, bikes, etc.

## US Companies Pull-out

Sino Japanese war of 1937 – pressure on Japan domestic non-war spending. Foreign exchange was revised leading to the skyrocketing of import prices with the decline in the yen exchange rate. Feeling the mounting pressure, the Big Three finally discontinued production in 1939 and withdrew from Japan. The Automobile Manufacturing Industries Act of 1936 positioned the automobile industry in a key role in the war effort. The Ministry of War classified motor vehicle manufacturing as a munitions industry. As of 1938, automobile manufacturers had no choice but to focus on the production of trucks, rather than cars, and some were eventually required to produce other kinds of munitions as well

It was clear to Japan that its imperial ambitions in China and east Asia were closely related to the Automobile industry. It was therefore not acceptable to have such key sector in foreign hands. The several policies taken to create an independent Japanese auto industry made it possible to fight a war. The outcome of most wars is closely related to technology. A nation armed with bows and will bow to a few men equipped with sophisticated weapons. This was similar to what Japan faced at the close of the WW2 when they were expecting a street-to street fight with American Invaders who came in instead with a nuclear bomb!

Ministry of Commerce and Industry followed Ministry of War in viewing automobile manufacturing as a "comprehensive" industry, because of its interdependence with a whole range of related industries in the provision of parts. Premise that the development of the automobile industry could serve as a model for industrial expansion in other sectors as well. The electronics industry, communications and aircraft manufacture were moving concurrently with the automobile. Government granted the automobile industry a key position in the development of Japan's industrial infrastructure. Large-scale investments in plants and equipment, not only to cope with the increase in demand accompanying the steady growth of the Japanese economy, but also to prepare for imminent trade liberalization. Investments in equipment were focused on the introduction of special-purpose automatic transfer machines. Beginning in 1955, manufacturers concentrated on introducing these machines to certain critical processes and applied them especially in the machining of engine parts, such as cylinder blocks and cylinder heads. These various measures helped bring about the rapid automation of Japan's automobile production system

During the War Japanese companies were allowed only to produce for the support of the war effort. this restricted them to the production to trucks and utility vehicles rather than luxury models. In the rehabilitation and reconstruction after the war, there was a new impetus for the development of passenger vehicles. Accordingly, construction of Toyota's Motomachi Plant started in 1958, and Nissan's Oppama Plant in 1961; Isuzu also built its Fujisawa Plant at this time. At this time, the Americans had had more than sixty years of unbroken experience in automobile technology. The factories were old. The new Japanese reconstructed factories used the newer technologies that were not available at the creation of the main US manufacturing base. They were therefore able to leapfrog the industrialized manufacturers of Europe and America

They continued with steady growth in the domestic and export markets, the implementation of new technologies to increase productivity became a top priority for manufacturers beginning in 1965. High-speed automation was introduced when the use of special-purpose transfer machines was extended to each stage of production. To optimize the integration of automation within the production process, new factories were built between 1965 and 1974 to accommodate the new technologies. These developments laid the groundwork for the subsequent introduction of robot technology and also boosted the ability of workers to perform multiple tasks. From about 1970, the

use of digital technology for specific tasks was expanded when all these operations went on line, leading in a short while to computerization of the entire manufacturing process from the earliest stage of product development through final production, on-line management of the supply of parts and materials.
Furthermore, during the 1970s, the steady introduction of new robot technologies gradually eliminated the need for humans to perform dangerous work in manufacturing operations. A resource disadvantaged Japan was always conscious of efficient use of fuel and other raw materials. The United States, through their client regimes in the Oil-rich middle-eastern countries as well as high domestic production, operated with a different mindset until the Oil embargo of the 17973 Arab –Israeli conflict. All along, Japanese cars had to meet stringent conditions worldwide. Fuel efficiency and conservation was a new field to the Americans. Emissions-reduction technology already in the Japanese system long before it became the norm worldwide. In 1975, for example, the cost of exhaust emissions research amounted to 36% of that year's total R&D investment by the automobile industry. Investment into gasoline efficiency research also took a high toll on the R&D funds

### Report Card

Japan dominated the Automobile Industry. It created the National Industrial Development which, as the designers expected led to success in other areas such as Electronics, Robotics, IT, Rail, Civil Infrastructures etc. Other Asian Countries such as Korea, China, etc are waking up to just that same model in our time!

## India Outsourcing & Collaboration

We have seen how that the new paradigm redefines society. It may not serve a very useful purpose to compare the developments in our nation to the industrialised countries of Europe and America. It is however instructive to look at some developing countries which only 30 years ago were either at the same level with us or worse off. Countries in the Pacific ream (the Asian Tigers) India, Thailand, China, etc. come to mind. Again, even in this category, Korea and Taiwan again are hard acts to follow. They have so developed their basic industrial infrastructure that to continue to classify them with developing countries in a historical hangover. Right now, Taiwan ranks next to the USA and Japan as the third largest producer of microprocessors in the world! Ahead of Germany, or any other European powers!.

The case of India is particularly interesting. A nation burdened with overpopulation whose land space has been continuously cultivated over several millennia and hardly has room to grow. A nation torn apart by constant internal strife and external challenges. Between 1980-1985, India was so poor that the greatest foreign exchange earner for the nation was the “Western Union” remittances of Indians in Diaspora. Per-capital Income of India was no more than half to one third of Nigeria’s during the oil boom days! In education, it was common knowledge that the typical Indian graduate of the sixties and seventies could not be compared to, say a UI graduate.

### IT Revolution

India’s acquisition of IT came largely because of the cheap labor of its educated underemployed university graduates in science and technology. Many of these had attended the IITs developed in six locations by the first post-independence government as the engine for India’s advance to the league of developed nations. Companies in Western Europe and the United States outsourced much of their IT work and services to India and the underemployed Indians used that as a stepping stone to become Masters in the same technology areas. In a short span of about fifteen years, India embraced the new Information Age paradigm. It has become a major force in the IT Industry: The statistics:

"*The Indian Information Technology industry accounts for a 5.19% of the country's GDP and export earnings as of 2009, while providing employment to a significant number of its tertiary sector workforce. More than 2.5 million people are employed in the sector either directly or indirectly, making it one of the biggest job creators in India and a mainstay of the national economy. In 2010-11, annual revenues from IT-BPO sector is estimated to have grown over US$76 billion compared to China with $35.76 billion and Philippines with $8.85 billion.[1] India's outsourcing industry is expected to increase to US$225 billion by 2020. The most prominent IT hub is IT capital Bangalore. Even though Bangalore is the leader it will slip to the second position by 2016 with Chennai leading. The other emerging destinations are Chennai, Hyderabad, Trichy, Coimbatore, Kolkata, Pune, Mumbai, NCR and Kochi. Technically proficient immigrants from India sought jobs in the western world from the 1950s onwards as India's education system produced more engineers than its industry could absorb. India's growing stature in the Information Age enabled it to form close ties with both the United States of America and the European Union.* [2]"

The present state of affairs in Indian economic performance can be compared to the situation in the 1980s when its foreign exchange activities were dominated by the remittances from its Nationals in Diaspora. "Last year, remittances to Asia amounted to $8.9 billion for Bangladesh, $27 bn for

China, $30 bn for India, $6.5 bn for Indonesia, $2.2 billion for Nepal, $1.8 bn for Malaysia, $7 bn for Pakistan, $16.4 billion for the Philippines, $2.7 bn for Sri Lanka, $5.5 bn for Vietnam and $1.8 bn for Thailand, according to International Labour Organisation estimates." [9]

The gross revenue generated by the software industry in India has now more than overtaken remittances and now contributes more than 5% of the GDP in a well diversified economy. If Nigeria continues to pumps one million barrels of oil a day for a whole year. At a conservative rate of $100 dollars per day, 365 days in a year, we will make $70 billion dollars. India is projection 205 billion dollars from outsourcing by 2020!

That was just before the meltdown on NASDAQ and Dow Jones in 2000 which affected the Indian stock exchanges. After a debacle, the software industry market cap has resumed a bullish path and has reaching US$ 55 billion by end of June 2000![9]. In a year, the market capitalisation was over 2000 per cent! This level of confidence in the Indian Industry is quite phenomenal!

In the past, Indian professional would go begging, cap in hand to be allowed into Europe or North America. The tide has now turned. Some of these countries are now amending their laws to enable Indian software specialists to come in. They have seen that partnership with India gives them competitive advantage. Germany, in 2000, upon discovering that it is falling behind in the competition for the share of the software market is desperately wooing Indian professionals in its search for Indian partnership

## The Maruti Story

Up till the Mid-80's, there was only one practical passenger car in India: The Hindustan Ambassador. With deep roots in Oxford England, production in India started in 1949 [4]. Governement policy was to promote local manufacturing of cars and discourage import. At a time when Nigerian students from the West brought the latest luxury models home, their Indian counterparts went home to ride motor bikes. It did not matter even if they had the money because Indian Government extracted punitive taxes each year from owners of foreign made vehicles that only the very rich could afford to own one. I painfully remember this example; After the home-going shopping of a Nigerians from

Canada in 1984, one Indian fellow student remarked that if he had the same amount of money the Nigerian had spent on consumable items, the most reasonable thing for him to do was to go back home with a Textile Mill! That was the effect of Government policy on the Indian psyche!
The Indira-Ghandi Government also had laws to protect the Indian Machine Tools establishment which were faithfully adhered to until 1983 when India decided to open its doors to the fledgling Japanese Suzuki Corporation. Suzuki was chosen by India over larger players such as Toyota, Nissan or Mitsubishi and temporarily suspended some of its socialist emphasis and allowed the company the kind of breaks that got it up and going. The story today is that Maruti Suzuki is the largest Car maker in India and those poor students of the '80's are now in a position to export cars to Nigeria! The relationship was not all smooth-sailing; an incident in this relationship is worth noting.

*"Initially R.C.Bhargava, was the managing director of the company since the inception of the joint venture. Till today he is regarded as instrumental for the success of Maruti Suzuki. Joining in 1982 he held several key positions in the company before heading the company as Managing Director. The Government nominated Mr. S.S.L.N. Bhaskarudu as the Managing Director on 27 August 1997. Mr. Bhaskarudu had joined Maruti Suzuki in 1983 after spending 21 years in the Public sector undertaking Bharat Heavy Electricals Limited as General Manager. Later in 1987 he was promoted as Chief General Manager, 1988 as Director, Productions and Projects, 1989 Director, Materials and in 1993 as Joint Managing Director.*

*Suzuki Motor Corporation didn't attend the Annual General Meeting of the Board with the reason of it being called on a short notice. Later Suzuki Motor Corporation went on record to state that Mr. Bhaskarudu was "incompetent" and wanted someone else. However, the Ministry of Industries, Government of India refuted the charges. Media stated from the Maruti Suzuki sources that Bhaskarudu was interested to indigenise most of components for the models including gear boxes especially for Maruti 800. Suzuki also felt that Bhaskarudu was a proxy for the Government and would not let it increase its stake in the venture.If Maruti Suzuki would have been able to indigenise gear boxes then Maruti Suzuki would have been able to manufacture all the models without the technical assistance from Suzuki. Till today the issue of localization of gear boxes is highlighted in the press."* [6]

Despite its success, the issues of nationalism remains. Each side needed to get the most from the relationship. It turned out the in India, Mr Bhaskarudu looks like a hero – someone who wanted more for his country in the partnership. Investigations into the Suzuki's charge of "incompetence" against Bhaskarudu was viewed by insiders in the company from this perspective:

"*If the gear box is indigenised, Maruti could start producing all its cars without any technical assistance from the Japanese company, … Suzuki feared that Bhaskarudu would not only succeed in procuring the gear box technology from the Japanese collaborator, but it would also result in Suzuki giving away its last technological trump card in the joint venture."* [7]

Indian auto industry is certainly a success story at this point in time. Other companies – notably Tata Corporation are also in the fray while the "old Amby" (The Hindustan Ambassador) trudges on

## China: The Giant Wakes!

### The MagLev Project

*"It may have been a historic coincidence that when China started its economic reform process, economic globalization was getting stronger. Unlike their forefathers 200 years ago, the Chinese did not reject the idea of opening up to the world in 1979—maybe because China had suffered too much humiliation and poverty from its isolation during the past 200 years."* [10]

The story of the Chinese economic epiphany is a developing story. In 20 short years of a change in strategy, they have become the second largest economy in the world. That is sufficient testimonial to their successful rise from number 25. I watched a live event in 1984: An American company in the was shutting down a factory in the US because of change in technology made the manufacturing practice at that particular factory obsolete. They wanted to move from a labour-intensive method to a fully automated one. A Chinese concern decided to buy the obsolete factory including the expertise of the workers in the plant to completely dismantle the factory, carry it to China and set up the factory and make it work for some months in China! The video of the dismantling was shown live and not a few people took their turns to mock the underdevelopment of the Chinese. That was 1984! Who is laughing now? The Chinese knew that the shut down factory was still okay for their level of development in 1984. They had a large population and need labour-intensive factories to keep them busy. They knew they could run that factory efficiently. They got all the help they needed and they succeeded. They did not need IMF or some Harvard-trained person to advise them. They were self regarding and world regarding. They knew their place in the world!

The same excellent strategy accompanied several other Chinese Technological acquisitions. Another example is the recent foray into Magnetic Levitation Rail system. The Chinese have the population to create the scale of use that can make the technology economical to operate. They bought the technology from the Germans who fully built the Maglev Cars that were airfreighted to China. Yet the Chinese negotiated to use local technology to design and build the super accurate infrastructure and tracks on which the train would run. In that kind of cooperative venture, the technology is more than 50% Chinese even at the beginning! A before and after assessment of the Chinese experience is best stated as follows:

*" … At that time, all the Chinese were equal, but they were equally poor. I would consider 1979 a historical turning point in modern China. That year Deng Xiaoping, the greatest man in contemporary China, decided to change this situation and launch a policy of reform and opening up to the world. Deng Xiaoping said, "Poverty is not socialism. We should make economic development the top priority of all priorities." And he advocated China's transformation from a planned to a market economy. With this transition, 1.3 billion people came to understand a very simple truth—that if they worked hard, they could have a better life. It is this simple truth that has made the spirit of entrepreneurship come alive in China again."*

## Our Response

**1. Curriculum and Executors**

Our topic today is supposed to be focused on the way the Engineering curriculum can enhance national development. Two facts have made me treat the topic the way I have apparently gone astray to other issues – especially that of technological paradigm shifts. One reason is that the definition of engineering itself it linked to the technological paradigm of the times. We must paint engineering, as it were, on the canvas of the technological paradigm of the day. If we fail to do so, what we are doing is not engineering.

The second point is that curriculum in and of themselves are nothing. The execution and the executors of the curricula are everything. For many years I recall that the topic of calculus of variations was always on the curriculum of virtually all our engineering programs. However they did not get taught because the teachers involved were not themselves well instructed in that topic. The same goes for the Computer, programming and IT components of our syllabuses. We will have to orient our curricula in the light of the technological paradigm and have capable hands to deliver such curricula. Before we do that, we will need to up our game as a nation. In so far as technological understanding is concerned, we are still joking! I have evidence to support that position. We only need to compare our national attitude with that of nations such as Japan, India and China as they lifted themselves up and left the posture of servitude to the Western

Powers. Such sense of National call of duty was re-enacted by South Korea and its Engineering achievements are now to be compared to that of the top economic powers in the world. It is the quality of our national resolve, based on the enormity of the problem that we will have to look at.

**2. Hard Engineering, Soft Engineering**

At Government level, serious research is not looked at as an important thing. This can be seen from the level of importance that Ministries such as Science and Technology is given. I was privileged to be selected on an intensive exploration of the German Research and Development System earlier this year. I was overwhelmed to see the critical importance that the German Research powerhouses such as the Fran hover, Max Planck and the Alexander von Humboldt Systems play in the technological innovations typified by great German companies such as Siemens, BASF or Bayer. These intellectual organisations handle most of the grants that researchers in the Industry and Academia use to develop world class products to put the Germans at a competitive edge worldwide. What do we have in response to these?

Of course we have the Petroleum Technology Development Fund PTDF, The Tertiary Education Fund TET Fund, and several others. Of course these do not have the kind of moneys available to the Germans. But who and by what intellectual rigour do we manage what we have? Do we give the leadership in the management of this the serious treatment we will need to give to the management of our football team? Are they above politics and the mundane “purchase of bullet-proof vehicle” level of silliness? If you doubt me, visit the Abuja offices of the TETFund and see the bearing and carriage of the typical officer there and compare the resources available to him to what you can see in any typical university laboratory. The former are growing fat and the latter growing lean!

It would appear that all the blame should go to government. That is hardly the reality either. I was part of a team that analysed the PhD these that were done in Nigerian Universities in the past three years. By the end of three intensive days, we were able to reach the unpleasant conclusion that more than 75 percent of the Engineering PhDs in Nigerian Universities are now focused on Soft Engineering. Here, you can get many papers published in low quality journals at a very fast rate. Hard engineering, defined by measurable solution to problems arising in Physics (or now chemistry and biology) of economic importance, are a scant 20% of the endeavours. If you populate the universities with people with such weak Hard Engineering backgrounds, how are you going to get national development?

**3. What new Universities are doing**

In the Western countries that are extremely sensitive to technological paradigm shifts, you can easily see what they consider important by the programs they are willing to fund and support. A new University was created in the Canadian province of Ontario in the few years. I was intrigued by the curriculum and programs that constitute Engineering in this new University:

Here are the Department and Programs at the new University of Ontario Institute of Technology:

**Faculty of Energy Systems and Nuclear Science**

- Energy Systems Engineering
- Health Physics and Radiation Science
- Nuclear Engineering / Nuclear Engineering and Management
- Nuclear Engineering (Doctoral program)
- Nuclear Engineering (Master's program)
- Nuclear Power Bridge
- Nuclear Technology (Graduate Diploma)

**Faculty of Engineering and Applied Science**

- Automotive Engineering (Master's program)
- Automotive Engineering / Automotive Engineering and Management
- Electrical and Computer Engineering (Doctoral program)
- Electrical and Computer Engineering (Master's program)
- Electrical Engineering / Electrical Engineering and Management
- Engineering Management (Graduate Diploma)
- Engineering Management (Master's program)
- Manufacturing Engineering / Manufacturing Engineering and Management
- Mechanical Engineering (Doctoral program) ▪ Mechanical Engineering (Master's Program)
- Mechanical Engineering / Mechanical Engineering and Management
- Software Engineering / Software Engineering and Management

There are many world class universities in Ontario offering Engineering; This new University is not following the footsteps of any! They are looking at the technological paradigm shift and preparing their nation to have a competitive edge! They can also see the way Energy will likely dominate the next technological era, hence, they are not satisfied with a faculty of Engineering, sans civil, sans chemical, but add a whole faculty of Energy systems and nuclear science!

## SaaS, PaaS and Tomorrow's Industry

Tomorrow's economy is about data, Green Energy and Large Control Systems. A recent edition of the Economist depicts the new data companies as the equivalents of yesterday's oil prospectors.


How does engineering training respond to these realities? Business as usual will simply ake us irrelevant to the goals and aspirations of our students. We shall focus in the conclusion of this paper on specific implications of the software and evolving manufacturing paradigms.

In the past few years, software was something you purchased and owned. When a new version arose, you could decide to make a new purchase or stay with the older version if it continues to meet your needs. This applies to applications software as well as operating systems software. That paradigm has all but changed. With Microsoft windows announcing that there will be no version 11 or 12, instead, they will continue expanding and improving the version you have through updates, we are into the era of Software, no longer as a product to be purchased but rather, it is now a service. SaaS is the acronym for Software as a Service.

The 3D modelling, Simulation, Analysis and CAM software we have in a product like Fusion 360 is a quintessence of the SaaS paradigm. The business model that allows our students to have full access to the software creates one level of advantage that we can use to modify our training strategy. This removes one aspect of our barrier to entry of this technology of using simulation and analyses packages.

Fusion 360, for example, can reside on your system, but the simulation and analysis – at least the heavy-lifting aspects, can be done in the clouds. That means that you do not necessarily require very powerful systems to analyze complicated models. Autodesk further enables us by allowing our students to have the cloud credits to execute their simulations free!

With these advantages, there is an opportunity to take a new look at the way we instruct on Mechanical Design as well as doing an original thinking on our S2P gap response. In the next section, we will take a look at a simple example to illustrate these ideas.

**A Simple Example**

Engineering students are usually introduced to component design via the strength of Materials course with the example of a simply supported beam. Modern software allows us to be more ambitious. For example, consider a curved bar in the form of a quadrant that is fully built in at one end and loaded at the other end in such a way that the lateral sections of the bar is free of all loads and completely unconstrained.

We shall look at the old way of designing and optimizing this bar. Go through the steps of theory and mathematical preparation needed to understand it through the current historical process. We shall use a Computer Algebra System to visualize the solutions for the purpose of comparing it to a completely new way of learning about the same problem to the point of optimization using the Just-in-Time paradigm we are proposing as a new instructional model to replace the existing way of doing things.

This, for simplicity is modeled as a plane stress case where the third dimension is small compared to the other two. The conservation of momentum and the generalized Hooke's law in the case where all body forces are negligible here means that,

$$\text{div grad tr } \mathbf{T} = 0$$

contains the compatibility restrictions on the displacements to produce single-valued strains (compatibility equations) in terms of the stress tensor as well as the two governing laws. ($\mathbf{T}$ is the stress tensor, and the above equation is to take the divergence of the gradient of its trace) The traditional approach to this problem begins with a re-derivation of these 2-D governing laws on account of the polar nature of the problem. Hence most texts rederive the governing equations in Polar coordinates by taking a free-body diagram in this form:

This does not change the governing equation in any way as the purpose of the derivation is to express the terms in polar coordinates.

**Solution.**

The equations here are solved by the Airy Stress Function which proposes the existence of a scalar function that can be differentiated twice to obtain the unknown stresses. This function, , is easily shown to be bi-harmonic so that,

$$\nabla^4 \phi = 0$$

In this easy case, the method of separation of variables leads to the general Michell solutions,

$$\phi = \left(A\, r^3 + \frac{B}{r} + Cr + Dr \log r\right) \sin\theta$$

We are now able to solve for stresses, strains and displacements by taking the appropriate derivatives, after computing the constants $A, B, C$ and $D$ that satisfy the boundary conditions of the problem. In order for this to be possible, the boundaries must be very simple indeed and the loading itself must also be simple. A general case of couples and forces at the single end could easily create complications in some of the boundary conditions.

For the simple case here, we deployed Symbolic Algebra to compute the Von-Mises Equivalent stresses at the tow surfaces where loads are highest in figure 3. As a result of the plane stress assumptions here, the result assumes there is no change in the stresses along the cross section. We can also plot the stress distribution along the radial cross section as shown in figure 4.

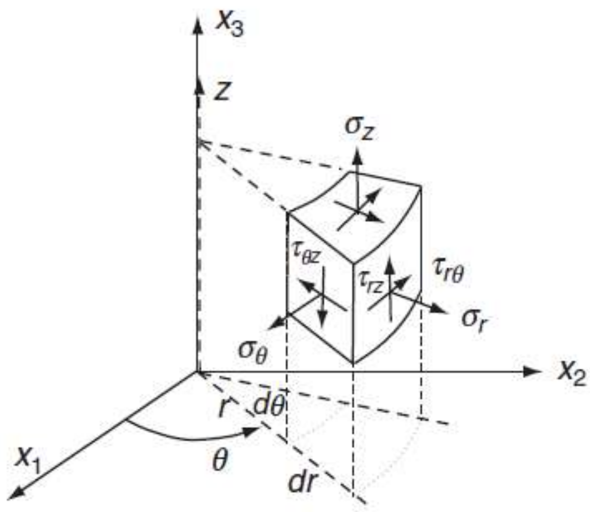
**Design**

From a Mechanical Design perspective, the absence of stresses in large portions of the mid radial sections of the loaded bar suggests a thinning of the bar in the middle could lead to a more optimal design and we can go on to show this to the students.

**Method Analysis**

In order to show students the logic of the optimizing of the design of a simple loaded bar, the following background preparation must be done beforehand:

1. Governing Equations
2. Re-derivation, in Polar form, of equations already known.
3. Solution Methods of Partial Differential Equations
4. Special case of Michel constants
5. Computations of the Equivalent Stresses for optimization




These mathematical exertions are necessary and a part of the engineering training. However, they occur at a point where the focus on design and optimization is lost in the Mathematical jungle to which we have led the students.

At the end of the exercise, the solutions obtained, though of historical usefulness and important as the lead to the modern numerical procedures, contributes little to the understanding of the design process at this stage. It is an avoidable distraction.

**A better way**

It is proposed here that we avoid the historical path in the instruction given to our students at least at the undergraduate level. Instead, we should be goal oriented in the specific design and production skills they are required to attain in the competitive market place where getting good products to the market is the key.

The question is to be able to do this without sacrificing the broad engineering view of the problem where, computations actually are not mere numbers, but the provision of valuable insight on the basis of which deep optimizations and economy can be achieved. To achieve this, we propose a "Just-in-Time" approach to the dissemination of the underlying theory.

1. Two key skills need to be learned at a much earlier stage of the student's preparation: 3D Solid Modeling and Differential Geometry (Tensor Analysis).
2. Add the skills in the use of computer algebra as a mathematical calculating tool. What the spreadsheets are to the modern accountants is, in our view, what the available computer Algebra systems ought to be for the modern engineer.
3. The student goes ahead and does a 3-D solid model of the curved bar. (30 mins). Proceeds to a simulation of the bar by applying loads and constraints.
4. Use the optimization tools to set acceptable stress levels and see, in a graphical way, what the cross section of the bar ought to be in the first place.
5. In a later course, after the students have mastered playing with design tools this way, lead them to the theory of Airy and other stress functions with the solutions of the governing equations. Rederivation unnecessary. CAS will give the equations in any system of choice.
6. Teach the finite element theory behind the simulations to enable the students better appreciate and understand the results coming out of the solid modeling toolboxes.

Some of the final steps can be made available as options. In this way, the student, while not following the historical development of the theories, has learned to see the design goals of the problems he is truing to solve. He has not been diverted from that goal by the mathematics. By the time he is learning the mathematics, it is clear that the additional knowledge assists him in

1. Seeing the limitations of the simulation results he is using.
2. Understanding how to read the data that the computer is supplying after he has specified the loading and constraining conditions.
3. Understand how to properly specify loads, prescribe symmetries and models reductions that should result from them.
4. Understand how to optimize geometries for applications and see the implications.

Solve problems that are completely out of the scope of the theoretical closed form solutions while in school and so be able to relate to the realities of engineering practice.

## Conclusion

It has been demonstrated that the close connection between a nation's economy, its engineering and technology instruction are closely related. Despite the fact that we are not policy makers in the wider national scope, the kind of products we send to the market can decisively affect the fotunes, not only of the students themselves, but the nation at large. Engineering must respond to technology paradigm shifts or it becomes irrelevant. We lost the Industrial Age, the technological paradigm shift of the second industrial age that created chemical, automotive and other industries. We are at the cusp of another global paradigm shift that mixes data with industrial production. We will need to become smart so not to carry the same can again!

## References

**About.com** (2013) History of the Internal Combustion Engine, http://inventors.about.com/library/weekly/aacarsgasa.htm#ic, Accessed 2013

**Dutson, A. J**., Todd, R. H., Magleby, S. P., & Sorensen, C. D. (1997). A Review of Literature on Teaching Engineering Design Through Project-Oriented Capstone Courses. Journal of Engineering Education, 86(1), 17-28

**Freed, Alan D**, Soft Solids, A primer to the Theoretical Mechanics of Materials, Springer International Publishing, Switzerland, 2014. 300pp

**Gurtin, Morton E, Fried, Eliot & Anand, Lallit**, The Mechanics and Thermodynamics of Continua, Cambridge University Press, 2010, 695pp

**Klingbeil, N. W., & Bourne, A.** (2013, June). A national model for engineering mathematics education: Longitudinal impact at Wright State University. In Proceedings 2013 ASEE Annual Conference & Exposition

**Morris, E,** (2007) From Horse Power to Horsepower, www.uctc.net, University of California, Accessed 2007

**Maruti Suzuki**, India http://en.wikipedia.org/wiki/Maruti_Suzuki, Accessed April 2011.

Iype, G "**Bhaskarudu: The Man Suzuki Loves to Hate**" Rediff on the Net, http://www.rediff.com/business/sep/22maruti.htm, 1998

**Olunloyo, VOS**, Quoted from Purdue University, "History of Mechanical Engineering", http://www.ecn.purdue.edu/ESCAPE/fields/mechanical/history.html, UNESCO Pub. No. 810.338.0, pp45-59, 2001

**Sengupta, D & Mishra, P**, "**Are IT jobs losing sparkle?**", The Economic Times, http://articles.economictimes.indiatimes.com/2010-08-27/news/27608367_1_coresectoroutsourcing-sector-tech-firms 2010

**India IT**, http://en.wikipedia.org/wiki/Information_technology_in_India, 2010

**Ians**, "India hit as foreign remittances dry up", http://ibnlive.in.com/news/india-hit-asforeignremittances-dry-up/85672-2.html, 2011

**Yongtu, L**, "**China & the World Economy**", Peterson Institute of International Economics, http://www.iie.com/publications/papers/paper.cfm?ResearchID=529, 2011