

Engineers and Engineering Sciences in Development: Treatise of a Non-Engineer

Abul Barkat*

Abstract

The organisers of the 2020 Rajshahi Regional Seminar of the Bangladesh Economic Association have requested me – a student of economics – to deliver a Public Lecture that shall be of relevant interest to the Engineers. My Rajshahi University colleague, Professor Dr M. Moazzem Hossain Khan of the Department of Economics, insisted that I write a "thought-provoking" paper almost every other day. I gave much careful thought to the possible subject matter. Since this 2020 Rajshahi Regional Seminar of the Bangladesh Economic Association is an unusual joint venture with the Rajshahi University of Engineering and Technology's Faculty of Applied Science and Humanities – I thought it to be appropriate to write and talk about the possible role of Engineers and Engineering Sciences in facilitating development in the complex era of fourth&fifth industrial revolution within the orbit of globalisation.

The self-selecting idea of writing on the subject has been a difficult-to-accomplish task for me – a non-engineer. I tried to conceptualise, however, keeping the science of causality in mind.

After much thought into the logical links of the critical issues encompassing the theme, I contemplated it to be appropriate to respond to the following self-posed questions:

1. *Who is an engineer?*
 - *A designer and builder of an infrastructure?*
 - *A technology mover?*

* *Professor and former Chairman, Department of Economics, Professor and Founding Chairman, Department of Japanese Studies, University of Dhaka. E-mail: barkatabul71@gmail.com*

- *A development activist in a multidisciplinary team?*
 - *A pathfinder?*
 - *A thinker and doer of sustainable human well-being?*
2. *What is the development and developmental cooperation? Are these about*
- *Inter-country trade?*
 - *Sharing of knowledge and learning from each other (with people of other countries)?*
 - *Inter-country connectivity building?*
 - *Exploring each member countries' comparative advantage?*
 - *Maximise mutual benefit based on mutual trust and reciprocity?*
 - *A mechanism (ways and means) for ensuring accelerated sustainable development?*
3. *What role can engineers play in expediting meaningful development?*
- *Can play a role in isolation as technical personnel?*
 - *Can they play the role of a member of a multidisciplinary team?*
 - *Can play lead role?*

The treatise under discussion has two distinct dimensions, namely A. Development and Cooperation: Model, New Developmental State (NDS), and Developmental Regionalism, and B. Engineers as Prime Movers of Development and Cooperation. The presentation of these two dimensions under the "umbrella theme" might seem disjointed. It is so because, first, I wanted to put my thoughts on the essence of various dimensions of development and cooperation (irrespective of the role of any specific discipline including the engineers) encompassing, among others, issues and concepts of development model, New Development State (NDS), and developmental regionalism (with relevant lessons learned). Second, after setting the conceptual stage for development and cooperation, I have attempted to place the engineers and engineering sciences as lead agents and prime movers of development and cooperation for a "second nature-based" new industrial revolution¹.

Finally, I have concluded that an engineer is not just a technical person (expert), and engineers can be development leaders. However, to become the

¹ A major part of this paper is drawn from author's keynote paper titled "Role of Engineers in Development and Regional Cooperation: Thoughts of a non-Engineer" presented at National Seminar of the 53rd Convention of The Institution of Engineers, Bangladesh (IEB) on 15 January 2012. However, in this paper, I have made some major revisions and included some new analyses.

"leader of development cooperation", a paradigm shift in engineers' thought process is necessary.

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A. Development and cooperation: model; new development state; developmental regionalism

A.1 Development Model of Developing Countries: The Essence

Traditionally economists are tempted to understand and/or define development in increased Gross Domestic Product (GDP) and/or in high economic growth rate and assume that the benefit of such growth will trickle down. Contemporary economists also suffer from many "development myths": *"Today's wealthy countries achieved success through a steadfast commitment to the free market". "Neoliberalism works"; "Neoliberal globalisation cannot and should not be stopped"; "The neoliberal American Model of capitalism represents the ideal that all developing countries should seek to replicate"; "The East Asian model is idiosyncratic, the Anglo-American model is universal", "Developing countries need the discipline provided by international institutions and by politically independent domestic policymaking institutions".* All these myths have been explored and logically refuted by Ha-Joon Chang and Ilene Grabel.² Therefore, as social thinkers, we first need to clarify the essence of 'development'. In this connection, I think the following would be the best guide to follow:

1. Development is not purely an economic phenomenon but a multidimensional process involving reorganisation and reorientation of an entire economic and social system (as proposed by Michael Paul Todaro).
2. Development is about transforming people's lives, not just transforming economies (as proposed by Joseph E. Stiglitz).
3. Development is about expanding human freedom; freedom is the primary goal of development, and freedom is also the principal development means. Development is the enhancement of freedoms that allow people to lead lives they have reason to live (as proposed by Amartya Sen).

² Chang, Ha-Joon & I. Gabriel (2005). *Reclaiming Development: An Alternative Economic Policy Manual*. London: Zed Books.

Since 2000, most developing countries (DCs) have pursued Poverty Reduction Strategy Papers (PRSPs) as a policy framework to ensure and attract official development assistance (ODA) and promote development. However, in general, their implicit development strategy has been a close integration with the global economy through removing trade barriers, the liberalisation and deregulation of domestic financial markets, and increased aid-financed social expenditure to achieve the Millennium Development Goals (MDGs). The outcome was *growth in the gross domestic product (GDP) with little structural transformation*. Poverty rates, measured using 'crude' and 'linear' definitions, have been falling but only slowly, as insufficient productive and decent employment opportunities have been created for the rapidly growing population. As a result, the number of people in multidimensional poverty increased.

The global financial crisis and recession further exposed the weaknesses of this development model. It revealed the risks, uncertainties, and vulnerabilities of integration with the global economy dominated by the so-called financialisation of the real economy. Most developing countries (DCs) experienced a sharp slowdown, with a decline in real per capita GDP. Although growth has subsequently recovered, it is clear that new development paths are now required for sustainable and more inclusive growth, which meets the immense challenge of productively employing the millions of young people – new entrants to the labour market. New development paths are required to address the issue of rising inequality and the destructive power of innovation.

Without any ambiguity, I believe that the opportunity for rapid poverty reduction through the development of productive capacities and the associated expansion of productive employment is real and significant. It can emerge from (a) mobilising underutilised resources, as well as the addition of new capacity through investment in agricultural productivity, plant and equipment; (b) the diffusion of available technologies; (c) public spending on infrastructure, skills and capabilities; (d) increasing public spending on education, health and social security; and (e) the creation of new 'useful' products and markets. There is, however, no unique way to combine these elements into a single correct strategy for inclusive growth. Notwithstanding, there is ample historical evidence that a cohesive, robust, catalytic and effective State responsive to the needs of its constituents is one of the prerequisites for defining the content of a long-term development strategy suitable to discovering what works in a particular context of individual countries. Although finding out a single correct strategy may be futile, it is absolutely an excellent guide to keep in mind that "*A good economic policy is a policy whose long-term social benefit is positive*".

The modalities, role and reach of the State in national economic management have tended to fluctuate over time. However, in all dynamic developing economies and all countries now classified as developed market economies, the government has played an immense role in promoting and supporting economic development. From this standpoint, it is time to talk about a *New Developmental State* (NDS). This NDS traces its intellectual origins to the Structuralist school and the East Asian developmental state. It focuses on creating new productive capacities rather than "reallocating" given resources and putting given productive capacities to more efficient use.

One-size-fits-all will not work. Each NDS will need to choose the trajectory of development suited for its economy, ranging from the traditional path toward "modernity" through Rostow's well-established stages of growth, including industrialisation via textile and garments and other labour-intensive commodities, toward technological leapfrogging into services or skill-intensive capital goods. The NDSs must identify and promote the type of industrialisation which is best suited for the particular country. This type of search makes up a vital component of the new functions of the NDS and requires policy space. Rather than taking industrialisation as a given trajectory for all DCs, the NDS "searches" (tries, experiments pragmatically) for the optimal development path in its own economy, including choosing the optimal form of productive and development trajectories.

The NDS approach is more holistic and integrated, encompassing both economic and social development, and needs to ensure that such development is served by finance rather than the other way around. The internal and external conditions that existed in East Asia in the 1950s and 1960s no longer exist.

At the early stages of development, the initiatives of the NDS will not rely solely on market forces to generate the desired structural change and economic transformation. In order to accelerate growth, the NDS will need to carry out significant shifting and reallocating of national and possibly international assets and resources to the growth-enhancing sectors. For this purpose, the new developmental State in DCs should engage in a more strategic type of integration into the global economy that would enable these countries to integrate in a manner that is in their interest to do so, rather than pursuing rapid trade liberalisation based on current and given comparative advantage.

Rather than arguing that DCs should integrate with the world economy and produce according to their static comparative advantage, the analytical foundation behind the NDS is associated with the classical economic perspective, which claims that productive structure is not endogenous to the countries' endowment structure (in terms of its relative abundance of labour, skills, capital or natural

resources). However, that comparative advantage is very much influenced and co-determined by interactions between the internal and external environment in which it operates. While the mainstream model of the State is underpinned by the paradigm of free trade and free capital movements as being the optimal strategy for the world economy, the analytical underpinnings of the NDS define their optimal degree of openness, implying that structural changes arise from shifts in the world economy, over which most developing countries have not much influence.

The NDS model is thus underpinned by the theory of openness within a managed trade policy that may enable a country to concentrate its relatively scarce resources in areas of production where world demand is highly income- and price-elastic; additionally, from this analytical perspective, it needs to promote the diffusion of knowledge of the kind of learning needed for continuous upgrading of the quality of all of the local factors of production.

The success of the NDS will depend on good development governance or, in particular, the capacity to achieve and sustain high rates of investment and to implement policies that encourage the acquisition and learning of new technologies. In all cases, the allocation of public investment is the primary function of the NDS, along with the setting up of a pro-investment regulatory framework that would enable rapid catch-up growth that could accelerate economic development. Moreover, the State needs legitimacy and a genuinely representative State, which will largely depend on the State's legitimacy to ensure a consensus for the development drive. It is a question of political will that involves "development contracts" or a social consensus in support of the development drive. A further critical governance capacity is the ability to absorb external shocks.

The nature of the relationship between growth strategies and governance capabilities varies widely amongst countries, including the composition and the nature of the State itself. While certain conditions may work very well in some countries, they may not work well in others.

In pursuing *real development*, it is crucial to recognise the *capability traps* of many governments and organs of the State. Capability traps holding many governments back are related to *isomorphic mimicry* where governments copy best practice solutions from other countries that make them look more capable even if they are not more capable and premature load bearing where governments adopt new mechanisms that they cannot do work, given weak extant capacities. (Therefore) "Importing "best practices" and placing unrealistic expectations on

the presumption that the level of performance and pace of change achieved elsewhere is possible everywhere, including "here", is a temptation".³

A.2 Development Cooperation towards Building New Developmental State

The benefits of cooperation (regional, South-South, North-South) will be most incredible when a dynamic relationship is established in which policies carried out by NDSs and cooperation reinforce each other in a continual process of change and development. In such a dynamic relationship, regional cooperation supports the building of the NDS and the achievement of its objectives. The NDS in DCs, in turn, enhances and shapes the benefits of cooperation.

Domestic ownership and leadership of policies is a sine qua non for enhancing the development benefits of any development cooperation, whether North-South or South-South. Mainstreaming South-South cooperation, both interregional and intraregional, into the national development strategies is thus a necessary condition to ensure that South-South cooperation promotes rather than hinders the achievement of the development goals.

It is clear that, with current policies, globalisation has not fostered the desirable kind of structural change in DCs that could pull labour from less to more productive activities. An NDS would seek to use development cooperation to re-shape its integration into the global economy to enable the structural transformations necessary for creating decent and productive employment opportunities and achieving substantial poverty reduction..

Two central objectives of the NDS should be to promote learning and enhance resilience. Openness works positively only if the phenomenon of learning is suitably institutionalised on the policy side, involving appropriate government interventions that would make the domestic economy more responsive to change. In general, managed development cooperation can facilitate openness and learning in a far more rational and efficient way than the unmanaged global market. Developing countries should seek to capitalise on this.

Intensifying integration is also likely to be a valuable strategy because of the diversification of markets. Investment sources enable greater resilience. The differential responses of DCs during global recessions in the past demonstrated how strategic Southern integration could affect volatility. Those DCs relying more on regional markets were buffered somewhat from the sharp downturn in Northern markets.

³ Andrews, Matt., Lant Pritchett and Michael Woolcock (2017). Building State Capability: Evidence, Analysis, Action. UK: Oxford University Press (p.54)

There are several benefits which developing countries (DCs) can gain from regional cooperation. First, most of the DCs lack a sufficiently large and diverse home market (that could allow diversification of the industrial structure), and thus regional markets provide an essential economic space within which learning over time can take place. Second, there are significant opportunities for achieving economies of scale by providing various kinds of regional public goods that would benefit developing countries within regional groupings. Such regional public goods include various kinds of physical infrastructures supporting transport, communications and energy, regional science and technology infrastructure, and regional innovation systems.

In addition, regarding the agricultural constraints to development in DCs, reflected in their inability to generate surplus and guarantee food security for all, joint adaptive research with neighbouring countries, regional storage facilities, and coordinated investment programmes at the regional level can all make a difference. Moreover, 'financial deepening' can also have a strong regional dimension.

It is possible to identify several reasons. Southern partners may be motivated to engage in cooperation and mutual advantages obtained with DCS.

Firstly, there is a potential to create mutually beneficial market gains and opportunities for both partners.

Secondly, DCs offer access to natural resources which their Southern partners need.

Thirdly, regional prosperity and regional stability cannot be achieved without all the countries in the region.

Fourthly, the DCS can work jointly with Southern partners to articulate their familiar voice and exercise their collective influence in all forums.

A.3 Cooperation as Developmental Regionalism: Integration beyond Liberalisation

Developmental regionalism can be understood as a development-led regionalism that accepts globalisation as a historical trend but rejects the market-led approach to globalisation. Developmental regionalism aims to maximise the benefits of regional cooperation to achieve an advantageous insertion of the members' economies into world markets. This goal is not an end by itself but only a means to accelerate economic, social and human development.

Developmental regionalism is concerned with both the (a) internal economic development and domestic integration, while at the same time, with (b) strategic

integration of the regional trading blocs into the world economy. Developmental regionalism involves domains such as trade, variety of policy tools, and not only those traditionally associated with trading policies proper from tariff and non-tariff barriers, to subsidies, concessional loans, direct provision of infrastructure and other public goods, promotion of research and development and science and technology activities, State-owned enterprises and State-controlled mixed enterprises, and many others.

In tandem with its holistic vision of development, regional trade can also be promoted through the coordination of investment in strategic areas such as regional transport and other ancillary infrastructure. Prioritising investment in strategic areas of common interest and constraints can help overcome the pre-existing bias against regional cooperation (including trade). As many developing countries are better connected to other continents than neighbouring countries, they cannot fully benefit from the potential gains of regional integration. The promotion of developmental regionalism should strengthen the structures, institutions, capabilities typical of the developmental State at the national level.

This kind of developmental regionalism aims to foster industrialisation and accelerate the economic and social development of member countries as goals per se and as a means of successfully integrating their economies in the global web of market relations. In the context of globalisation, new developmental regionalism strives to exploit the maximum benefits that can stem from negotiating with other blocks and economic powers from a position of relative strength, such as the one allowed by member States collective ability to act as a single player. The expanded regional market generated through inter-State cooperation and temporary protection policies for domestic capital contributes to secure benefits for domestic firms over their foreign competitors. Developmental regionalism assumes the need for gradual and sequenced trade liberalisation and conscious and planned policy actions enacted to build up productive capacities. Such productive capacities are seen as a necessary condition that will eventually enable domestic businesses to participate in the global market.

In most developing countries, the experience of developmental regionalism is still in its embryonic stage. African countries, supported by the AFDB and the NEPAD and other partners, are embarking on similar initiatives to create development corridors and redress long-standing infrastructural gaps. Although, in general, these initiatives are at a more incipient stage than those in the Asian region, notable examples are The North-South corridor, which connects Durban and Dar Es Salaam, and the Maputo corridor linking South Africa's northern and eastern regions to the port of Maputo. So far, the most successful examples of its practical realisation can be found in Asia. Indeed, the region where these

processes are most advanced in East Asia is a region where a positive, proactive view of integration has prevailed for a long time. Here are some examples:

First, the recent experience of trilateral economic cooperation between China, the Republic of Korea and Japan constitutes a successful example of developmental regionalism. Trilateral cooperation in North-east Asia began in 2000 and has been focusing mainly on environment protection, transport and logistics, finance, and research and development. In the manufacturing area, particular attention was devoted to the IT sector. The latter covered several areas, from telecom service policy to network and information security. However, the main strategic goal was the joint development of new technologies such as next-generation Internet, open-source software, and radio frequency identification (RFID) sensor networks. The three North-east Asian countries were aware of the critical role of IT for overall economic upgrading and industrial competitiveness. The countries representing this trilateral cooperation adopted proactive government commitments to generate synergistic effects in technological development and, more broadly, enhance their firms' international competitiveness.

Second, the Brunei-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA) is one of the sub-regional "growth polygons" that were established since the early 1990s to foster the process of regional integration among the member states of the Association of Southeast Asian Nations (ASEAN). As these sub-regional zones include impoverished countries, they face significant challenges. The BIMP-EAGA has tried to overcome these challenges by adopting the principles of developmental regionalism, promoting activities to enhance the economic capacity and prospects of lesser-developed countries to foster their integration into the regional economy.

Third, The Greater Mekong Sub-region (GMS) Program (ADB coordinated) can be a successful example of developmental regionalism. The GMS started in 1992, involves all the prominent actors around the Greater Mekong area, such as Thailand, China, and all the LDCs, ASEAN and ASEAN's development partners, including Japan. It is the only regional cooperation programme specifically targeting all LDCs in the region. The core of GMS is to enhance the infrastructure of industrial development in the region by implementing programmes in transport, telecommunications, energy, tourism, trade facilitation, investment, human resource development and agriculture. The basic strategy is to attract private investment to the region and facilitate cross-border trade, investment and tourism by strengthening infrastructure linkages. To enhance transportation linkage over the region covering three East Asian LDCs- Thailand, Viet Nam and Yunnan Province, and Guangxi Zhuang Autonomous Region of the PRC, the GMS programme introduced three economic corridor projects. These are (a) the

East-West Economic Corridor (Myanmar, Thailand, the Lao PDR, and Viet Nam); (b) the North-South Economic Corridor (China -Yunnan, Guangxi, the Lao PDR, Thailand, Viet Nam and Myanmar); and (c) the Southern Economic Corridor (Cambodia, Thailand and Viet Nam).

Fourth, China's *One Belt One Road (OBOR or yi dai yi lu)* initiative is the most talked-about mega-scale example of developmental regionalism having geo-economics and geo-strategic implications OBOR intends to connect more than two-thirds of the world population and open up the windows for the revival of global business and infrastructural development across countries. Arguably, OBOR is one of the most extensive development plans in modern history. Under the OBOR initiative, China intends to build massive infrastructure with pipelines and ports in Pakistan, bridges in Bangladesh and railways to Russia, aiming to re-createthe "Modern Silk Road" trading route that may kick start the new era in globalisation. OBOR has implications for expanding the renminbi (RMB) internationalisation, both in the real economies of Belt and Road host countries and in the London offshore financial market. OBOR initiative intends to connect two ends of Eurasia, as well as Africa and Oceania, along two routes – one overland corridor (the "belt") and one maritime shipping lane (the "road"). Under OBOR, China plans to construct projects in more than 70 countries along these routes. The Belt and Road initiative is expected to cost more than one trillion US dollars.

Globally, many debates are already in place about the possible causes and consequences of China's Belt and Road initiative: Is it to resolve the issue of managing China's excess surplus? Is it to promote China's hinterland? Is it a state-backed campaign for China's global dominance? Is it an aggressive stimulus package for a slowing economy? Is it a massive campaign for Chinese investment around the world? Is it to ensure China's dominance in the construction sector at the expense of local contractors in partner countries? Will this initiative increases the risk of debt distress in many countries? Will this make China the most prominent foreign creditor? Is this a part of "*debt-trap diplomacy*"? Will this initiative block sea trade or monopolise sea trade by China? Will this act as dual-use for commercial and military purposes? China will use this as a vehicle to write new rules, establish institutions that will reflect Chinese interests, and re-shape 'soft' infrastructure? The argument I have raised entirely is simple: Economic dominance accompanied by huge moral hazards can be dangerous!

a. Engineers as prime movers of development and cooperation

Now, before I enter into the complex domain of "Role of Engineers and Engineering Sciences in Development", let me –make a meaningful link between

what has been said above and what I want to say now – recapitulate the first broad dimension on "development and cooperation". First, I tried to argue that the one-size-fits-all type of traditional development model has failed to respond to the needs of sustainable human(e) development through meeting the challenge of productive employment of millions of young people and addressing the risks and vulnerabilities of integration with the global economy dominated by so-called financialisation of the real economy. This traditional model has generated slow growth in GDP without any structural transformation. Second, a new model termed "New Development State" (NDS) has been proposed in addressing the first issue. The development under NDS must be able to reorganise and reorient the entire economic and social system, transform not just economies but the lives of people, and expand human freedom. The NDS, based on the knowledge economy, focuses on creating new productive capacities (in which engineer's/engineering science has a vital role to play) rather than "reallocating" given resources and putting given productive capacities to more efficient use. This model encompasses openness with managed development policy, diffusion of knowledge and learning needed to upgrade the quality of all local factors of production, good development governance, 'search for the optimal path of development in specific economy, and alike. Third, Development regionalism is essential, which accepts globalisation as a historical trend but rejects the market-led approach to globalisation.

B.1 What is the Contribution of Engineering Science to Modern Life?

Engineering science has played a critical role in improving human quality of life in the last 50 years by developing better water supplies, sewer systems, wastewater treatment plants, designing buildings to protect us from natural hazards and provide health care, improving agriculture through water resource development and distribution projects, dramatically improving transportation systems.

The engineers whose work has helped reduce the death rate dramatically, which is one of the principal reasons the population has grown so dramatically in the last 150 years. For example, transportation improvements alone have enabled rapid migration of large numbers of people worldwide and increased the volume of raw materials and finished products in international trade 1000 times in the last century. Economic output has increased over 30 times, fossil fuel 40 times and industrial production 150 times in the last century. Some undesirable environmental, health and social impacts have come along with this growth, particularly in the last half-century.

b.2 A new human perspective is needed

In the last five decades, the world population has been more than doubled to 7.7 billion people, and the world's economic output has increased fivefold. This unprecedented growth is altering the face of the Earth and the composition of the atmosphere. Pollution of air and water, accumulation of wastes, destruction of forests, erosion of soils, depletion of fisheries, and damage to the stratospheric ozone layer threaten the survival of humans and thousands of other living species. Humans are conducting an uncontrolled experiment unprecedented in scope and scale that represents the reversal of natural evolution which produced clean air and water and increasingly complex and diverse ecosystems -- systems that made human evolution possible.

These changes – a result of unsustainable and inequitable production and consumption patterns – are likely to accelerate with the addition of 80 million people to the planet each year. We are – a society living off its natural capital, not its income. We are acting like a planet in liquidation – a bad business. Recognising that these trends placed humankind at a crucial crossroads, scientists around the globe, including 102 Nobel laureates, signed the World Scientists' Warning to Humanity (in 1992). The warning reads as follows:

We, the undersigned, senior members of the world's scientific community, hereby warn humanity of what lies ahead. A significant change in our stewardship of the Earth and its life is required if vast human misery is to be avoided and our global home on this planet is not to be irretrievably mutilated.

Despite these warnings, the entire Earth's living systems have continued to decline. Moreover, the degradation of natural systems is likely to accelerate with the addition of 80 million people to the planet each year unless strategies to meet human needs are made more sustainable and just. The fact is simple is that the current strategies to meet human needs are not sustainable.

It is appalling that eighty percent of the world's resources are consumed by 20% of its population. The world's poorest 20% earn 1.2 percent of the world's income. The income ratio of the wealthiest 20% to the poorest 20% was 28:1 in 1960; it was 192:1 in 2018. For 40% of the world's population, poor sanitation, malnutrition, and air pollution are still significant causes of illness and death. The rural poor will migrate and be transformed into an urban poor, and environmental health and social problems will multiply. For the first time in history, more people are now living in urban than in rural areas. Moreover, this urbanisation is nothing but slumization in the absence of concomitant industrialisation.

In the USA, air pollution is believed to kill more people than automobile accidents – more than 70,000 premature deaths per year, according to the EPA. By the time population growth stabilises this century, a five- to sevenfold increase in

energy consumption and goods will be needed to raise the consumption level in the developing world to that in the industrialised world. Agricultural production must increase threefold in the next forty years for all humans to have adequate nutrition – we are already appropriating the most productive 40% of the land-based biomass for human purposes. Simply to maintain the current unhealthy levels of pollution and waste loadings will require an 80-90% reduction in pollution generated per unit of economic output. It cannot be achieved by building more waste treatment plants or air pollution control devices.

The world will need an unprecedented two billion jobs in the next twenty to thirty years to employ the current 1 billion underemployed and unemployed people and the new job seekers who will enter the market. It cannot be done with economic activity that substitutes capital for labour, consumes large amounts of materials and energy and creates large volumes of pollution and waste. Paul Hawken points out that with a sextupling of population and increasing economic output over 100-fold, we have the reverse of the situation at the start of the industrial revolution, which was an abundance of natural resources and the ability of the biosphere to assimilate wastes. "Our thinking is backward: we should not use more of what we have less of (natural capital) to use less of what we have more of (people)."

There is increasing social and political instability worldwide despite the end of the Cold War and the increased globalisation of the economy (which the globaphobes argue contributes to the instability). According to UNCHR, there are 71 million refugees, 47 million environmental refugees, unprecedented migration from East to West and South to North, 74 regional military conflicts. The UN has seen its influence erode, and there is increased isolationism of significant powerhouses.

Apollo 13 said, "Houston, we have a problem!" – a societal problem caused by the "design" of an economic and social system that lives off its support system in a degrading, unhealthy and unsustainable manner. We will need a paradigm shift in the relationship of humans to the environment and each other – one in which humans live in harmony with both natural systems and each other. We cannot achieve these results with our current thinking.

As Einstein observed, "the significant problems we face cannot be solved at the same level of thinking we were at when we created them." In the next twenty to forty years, society must adopt new strategies that allow the needs of an expanding population to be met in an environmentally sustainable and equitable manner. However, our response to the situation so far has been irresponsible and dangerously inadequate. For example, based on the so-called cost-benefit analysis

of carbon emission, we recommend taxing carbon and giving a message to firms emitting carbon and contributing to climate change is OK as long as you pay a fee: This is immoral; it simply legitimises pollution.

The current *growth ideology* has captured our imagination to the degree that we believe that more of the same resource-intensive and pollution creating economic growth remains the best way to serve the common good. Economists' idea of *growth at any cost* is primarily an outcome of their intellectual failure to value things with high value or many intrinsic values. Examples include failure in putting appropriate economic, social, cultural, political and intergenerational values of consequences of climate change, of (rising) inequality, of inadequate sanitation, of non-portable water, of work absenteeism, of school dropout, of not immunising a child, of deaths and disabilities due to preventable causes, of crime prevention, of not getting a fair price (by the farmers), of construction of dams or irrigation system ignoring the value of social capital (ultimately a "lose-lose" scenario), of indiscriminate use of energy and fuel, of unjust trade in the era of globalisation.

We have known that a healthy environment is essential to human existence, health, and well-being for quite some time. Humans can live for about four minutes without air, four days without water, and four weeks without food. Plants, animals, and the habitats they occupy provide the food that sustains human life. The Earth and all its living organisms supply all raw materials for human activities. All economic, social, and community systems derive resources from and are a part of the biophysical system we call the biosphere. There is no inherent conflict between protecting the environment and a robust human economy since the environment supports all human activity.

b.3 Engineers towards a just and sustainable future

How do we create a life that allows all present and future humans to be healthy, have their basic needs met, have fair and equitable access to the Earth's resources, have a decent quality of life and preserve the biologically diverse ecosystems on which we all depend? Future scientists, engineers, and business people must design technology and economic activities that sustain rather than degrade the natural environment, enhance human health and well-being, and mirror and live within the limits of natural systems. We must dramatically reduce our economy's resource and energy throughput and minimise our ecological footprint to maintain the life support system that will make a sustainable future possible. It calls for a New Industrial Revolution that builds upon the information and biotechnology revolutions of the past half-century. It is to note here that the world population

will be stabilised at a level that should be within the short and long term carrying capacity of the Earth's finite resources. This level is of great debate and is probably between ten and twelve billion people, which we will reach within the next fifty years.

Now let us come to a serious point about our discipline- the science of economics. Economics is caught in the trap of *model-blind science*.⁴ Some of us even try to propose 'the' model and not the 'a' model. This *blindness* originates from not recognising that: *Correlation failing to establish causality is the death of causation*. It is not to say that models are useless. However, models are never true; but there is truth in models. Also, it is not unfounded that most economists (most model builders) have adopted a fragmentalist and reductionist approach to a social phenomenon, making unfounded universal claims, ignoring the social, cultural, and political context, reifying markets and material incentives, and having a conservative bias. More so, many assumptions that go into economic models – perfect competition, perfect information, and perfect foresight – are patently untrue. Also, economists' obsession with choices made by individual households or individual investors – hides the fact that preferences and behavioural patterns are "socially constructed" or imposed by the structure of society.⁵ Here it should be noted that Economics provides many of the stepping-stones and analytic tools to address the significant public issues of our time. What economic science does not provide is definitive, universal answers. The results obtained from economics proper must be combined with values, judgments, and evaluations of a moral, ethical, political, or practical nature. These last have very little to do with economics but everything to do with reality. Here comes the potential role and responsibility of Engineering Science (and all other natural sciences) because they ought to deal with reality holistically.

Based on the above-stated arguments and realities, it is time to raise issues of our common interest: What should be our vision towards sustainable future development? Let me forward *Eleven Commandments* that need to be internalised by the Engineering Sciences to accelerate sustainable future development. The Eleven Commandments are as follows:

⁴ To learn more about "Model-blind Science" which based on data-centric vocabulary fails to understand causal links and suffer from pretensions see, Pearl, J. & D. Mackenzie. (2019). *The Book of Why. The New Science of Cause and Effect*. UK: Penguin Books.

⁵ To understand more about what went wrong with economic models and assumptions behind, what's wrong with scientific pretensions of economists, why a model (or theory) is at best contextually valid and alike, please see, Rodrik, D. (2016). *Economic Rules. The Rights and Wrongs of the Dismal Science*. NY: W.W. Norton & Company.

1. ***We will use resources efficiently.*** Leading scientists have been calling for a considerable increase in resource productivity -- by a factor of 4-10 to increase wealth for 4/5 of the world's population and decrease environmental impact. It is critical because the industrialised economy is incredibly wasteful in using resources while the planet has a finite amount of resources and a finite ability to absorb and process wastes. In their thought-provoking book *Factor Four: Doubling Wealth, Halving Resource Use*, Ernst von Weizsacker and Amory and Hunter Lovins call for a revolution in energy and resource productivity and provide over 50 demonstrated examples of factor 4 increases in energy, material and transportation productivity from a variety of institutions around the world. With a few exceptions, they all cost less than conventional means of doing business and increased social and economic and environmental sustainability.
2. ***We will learn from and live within natural systems.*** Humans are the only species on Earth that produce waste that is not raw material or nutrient for another species. Also, we are the only species to produce wastes that can be broadly toxic and buildup for long periods. A sustainable society should eliminate the concept of waste. Waste is not simply an unwanted and sometimes harmful by-product of life; it is a raw material out of place. Waste and pollution demonstrate gross inefficiency in the economic system since they represent resources no longer available for use and/or harm humans and other species.
A sustainable economy would mirror nature's "circular" method of using matter and employ the concepts of design through which all waste would be the "food" (waste = food) for another activity. This idea is integral to industrial ecology. Metal extraction and conversion would be replaced by strategies to cycle existing metals through the economy continuously. For example, recycling aluminium rather than virgin bauxite ore reduces energy use by 95% and pollution by 99%.
3. ***We will use renewable resources at a rate less than or equal to the natural environment's ability to regenerate the resource.*** It means living off the income, not the capital -- e.g., practising sustainable forestry, sustainable fishing and sustainable agriculture. To cite an example, every ton of paper made of recycled fibre saves seventeen trees and cuts air and water pollution by 30-50%. Organic farming and agricultural production that minimise pesticides and fertilisers while conserving soil and water are safer and more sustainable.

4. ***We will rely less on non-renewable energy.*** Over 85% of the world's energy comes from fossil fuels. This form of energy use causes significant environmental and health problems such as black lung disease, air pollution, acid rain, oil spills and global climate change, to name a few. The desire for a continuing "cheap" supply of fossil fuels has had enormous military and economic costs to keep the oil and gas flowing worldwide, especially from the Middle East. Moreover, this fossil fuel dependence has been economically unsustainable for more than a few decades -- it took 10,000 days for nature to create the fossil fuels that society consumes in one day!
5. ***We will increase the production of durable, repairable goods and eliminate persistent, toxic and bio-accumulative substances.*** At the same time, we will eliminate disposable goods as much as possible and detoxify the production process by minimising the use and discharge of toxic substances. Products would be designed for disassembly so that the materials could be utilised in making new products. For example, several manufacturers (Volkswagen, Volvo, BMW) are redesigning automobiles to recycle at least 90% of the materials into new automobiles.
6. ***We will focus on providing the ultimate ends of products or services, not the products or services themselves.*** A key to resource efficiency is to understand products to deliver a service to a customer. For example, people do not want energy, and they want the service it provides, such as heat or light. Similarly, people want access to people, places, things and experiences, not necessarily increased transportation. An example of a company that has adopted this idea is Interface, the largest commercial carpet tile company globally, which now leases carpet. The lessee gets the service of the product -- warmth, softness, acoustic value, and aesthetics for a fee. When the carpet is worn out, Interface takes it back and recycles it into a new carpet.
7. ***We will create low energy consuming transportation systems.*** We must accelerate the development of alternative fuel vehicles that minimise and eventually eliminate dependence on fossil fuels and accelerate mass transportation.
8. ***We will create an environment where all people will understand their connection to the natural world and other humans.*** They will understand their "ecological footprint", i.e., they will know where products and services come from, where wastes go, and what they do to humans and other living species. They will appreciate that driving a car in Ohio may

cause flooding in Bangladesh through global warming or that cutting down forests in Brazil may deprive someone in Hungary of a lifesaving drug. For all people – led by professionals such as engineers – minimising their ecological footprint and "walking lightly" on the planet will be "second nature."

9. ***In today's world of (over) consumerism, an average person in a developed country receives 2,000 advertising messages per day oriented toward consumption.*** The public is often portrayed as a group of consumers, not citizens. However, increased consumption and material acquisition alone has not led to a happier, safer and more secure population. We will ensure that all current and future generations of humans can meet their basic needs, pursue meaningful work and have the opportunity to realise their full human potential personally and socially.
10. ***We will have timely economic, social and environmental signals that encourage environmentally and socially sustainable behaviour.*** The economic measures of success we use today, such as the GNP and consumer price index, discourage conservation and encourage waste, consumption, and the substitution of capital for jobs. The price of goods and services reflects all the profits to the producers but does not include all the social, environmental and health costs to the society. In a sustainable society, we would have more development, i.e., qualitative improvement in people and value-added to resource use, than quantitative growth in resource and energy-intensive economies. We need to think hard about full-cost (including social and environmental) accounting for economic activities, development of macroeconomic indicators that truly reflect societal well-being (e.g., Index for Sustainable Economic Welfare, Genuine Progress Indicator) and taxation, which taxes the undesirables (energy and resource consumption) and not the desirable (education, health, employment).
11. ***We will put all-out efforts so that nations act as a Global Family.*** The relationship between the developed and the developing countries must be changed. Industrial countries must reduce their consumption of the world's resources in the face of the desperate need of developing countries to improve well-being, health, reduce all forms of poverty and inequality, and social instability. Today, a child born in the US will consume as much of the Earth's resources and produce as much waste as more than 100 Bangladeshi children. We also need new approaches for transferring technology, training and education, good health and well-being, and

providing financial assistance to developing countries. These approaches must address population deprivation, improving women's educational and social status, the international debt problem, cooperation in all possible fields of humane development, and the need for sustainable economic strategies.

B.4 What should be the Role of Engineers and Engineering Education?

Let me be straight: Engineers – socially responsive and visionary ones – must lead this new industrial revolution and carry forward the above vision for human development and cooperation. The professional bodies of engineers are well-placed to make sustainable development a high priority in engineering and business -- both in practice and in the education of future engineers. They are in a place to promote codes of practice, education, mentoring programs and policy changes that will encourage the engineering profession to lead this revolution.

Let me forward one more issue to ponder over/on. A current fundamental problem is an underlying assumption (by many) that environmental protection should be left to environmental professionals. However, environmental specialists alone will not help us move toward a sustainable path. All humans consume resources, occupy ecosystems and produce waste. We need all professionals to carry out their lives and activities in an environmentally sound and sustainable manner. However, the truth is that the current education and training of most environmental professionals who are and will be employed by government, industry, academia and environmental organisations is narrowly focused and incomplete. Most of these professionals are trained in dealing with a subset of environmental problems such as air pollution, water pollution, or hazardous waste but are not trained to deal with environmental issues in an integrated and holistic fashion. Training focuses on controlling pollution and waste once created and removing environmental damage, rather than reducing or eliminating pollution and waste generation at the source.

I believe that designing a sustainable future requires a paradigm shift towards a systemic perspective that encompasses the complex interdependence of individual, social, cultural, economic and political activities and the biosphere. The future engineers must be much more interdisciplinary -- the lines between the traditional engineering disciplines must be much more fluid or removed altogether. Engineers will have to join forces with biologists, chemists, meteorologists, economists, planners, political scientists, ethicists and community leaders to lead society on a sustainable path. Since we will likely double the amount of housing and building construction in the twenty-first century (and

buildings utilise a tremendous amount of materials and energy), engineers must team up with other professionals to revolutionise construction. It is just one of many examples of much intended second nature-based new industrial revolution.

I believe that there is a unique role for engineers in the future. Rather than being the engineers that primarily design technologies to control or remediate pollution, I believe the engineers will be the interdisciplinary systems specialists. They will bring together, coordinate and manage all the specialists to solve complex problems promoting sustainable development.

Engineers must be better informed of the interdependence of environmental, economic, health and social issues, inform others and become leaders. In addition, all engineers must play a much more decisive role in the public policy process to provide the right incentives for industry and others to move on a sustainable path so that engineers can be encouraged and supported to design sustainable technology. If this does not happen, then the agenda will be set by others who neither know the benefits nor the limits of technology in a changing society.

Such a shift in the thinking, values, and actions of all individuals and institutions worldwide calls for a long term societal effort to make environmental and sustainability concerns a central theme in all education, particularly for engineers, economists and business people. If we are to achieve a sustainable future, higher education institutions must provide the awareness, knowledge, skills, and values that equip individuals to pursue life goals in a manner that sustains human and non-human well-being. It is critical since higher education prepares most professionals who develop, manage, teach-in and influence society's institutions. It is, however, essential to note that to the best of my knowledge to date, no engineering school has made design for the environment, industrial ecology, pollution prevention or the relationship of technological development to sustainability the cornerstone of engineering education. Here, I see a necessity for change in the mindset. Here, learning content must embrace an interdisciplinary, systemic approach to address environmentally sustainable development on local, regional and global scales over short-, medium- and inter-generational periods.

C. Some Concluding Remarks

I believe we have two choices as a society: First, continue business as usual -- promote population and rapid economic growth that maximises materials and energy and then head for the new horn of plenty, with no time for recycling, efficiency or restoration as the cure for all our social, health, political (and some say) environmental problems. Let nature set the limits through environmental collapse, poverty, inequality, malnutrition, social instability, and war. Let me put

it bluntly: One definition of insanity is doing the same thing over and over again and expecting a different result!

A second choice is for humans, as the most self-aware species that can learn very quickly, to take deliberate individual and collective steps to find civilised and cooperative ways to live in harmony with each other and the rest of nature. It means respecting and living within nature's limits, using energy and resources as efficiently as possible, maintaining the integrity of the life support system and helping all people meet their needs. This second choice is the best. Furthermore, "socially responsive" engineers are better placed to take up this challenge to make the best of the opportunity to design the knowledge base and technology that will lead us to a sustainable common future.