Efficiency and Beyond

The 2004 Dr P.R. Srinivasan Lecture

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by
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I am deeply honoured to be here with you this evening. To celebrate the memory of someone whose work I have admired for many years, in fact over many decades, is indeed a great privilege. Dr P.R. Srinivasan's life and work exemplify a dedication of the highest order to his science; a dedication he combined with no less a commitment to bring the benefits of that science into the lives of real people and for the solution of real problems in society.

Dr Srinivasan's contributions to our understanding of the concepts of efficiency are legendary. In many areas of the nation's economy, they are still the benchmark by which we judge the quality of improvement in our production processes. It is a tribute to his vision and depth of knowledge that the army of disciples he trained and mentored are now themselves the leaders of so many of frontline organisations, within India and overseas.

What I would like to share with you this evening is not about the many things that P.R. Srinivasan was so deservedly well known for but about a less well-known aspect of the contribution of this great pioneer in applied efficiency studies: the fact that he not only placed the goal of efficiency at the heart of all production processes but he was only too aware of the limits of doing so. Efficiency is, after all, as he sometimes stated, but one of the many goals we must satisfy. And who better than he to understand the possibilities and constraints of optimising complex systems?

Efficiency in a complex world

Today, our world has certainly become a system of such complexity that few could have imagined its full ramifications even a few decades back. The central question now becomes: how do we situate the classical notions of efficiency within the larger need to satisfy a broader set of national objectives? Societal goals that no one used to think of in the good old, simpler days – goals now considered to be of importance equal to that of efficiency, such as social justice, equity, fulfilling the right to livelihoods, environmental health and all the other things that we have grown to value over the past 30 odd years?

Is the pursuit of efficiency so supreme an objective of society that it over-rides all others? Does this single-minded pursuit have to drive our civilisation to destroy the very things on which we depend for our existence? What are the trade-offs and sacrifices we are prepared to make to achieve higher levels of efficiency? And who gets the benefits of greater efficiency – and who pays the costs? Is efficiency to be synonymous with profitability or is it meaning to be broadened to mean the care and protection of our one and only (and rather fragile) planet?

And, when it comes down to brass tacks, what is efficiency anyway? Is it a clearly defined concept? Would everyone agree to its definition? Is there any way to define it so that it encompasses the other concerns rather than being in a contest with them for our attention?

The many sides of efficiency

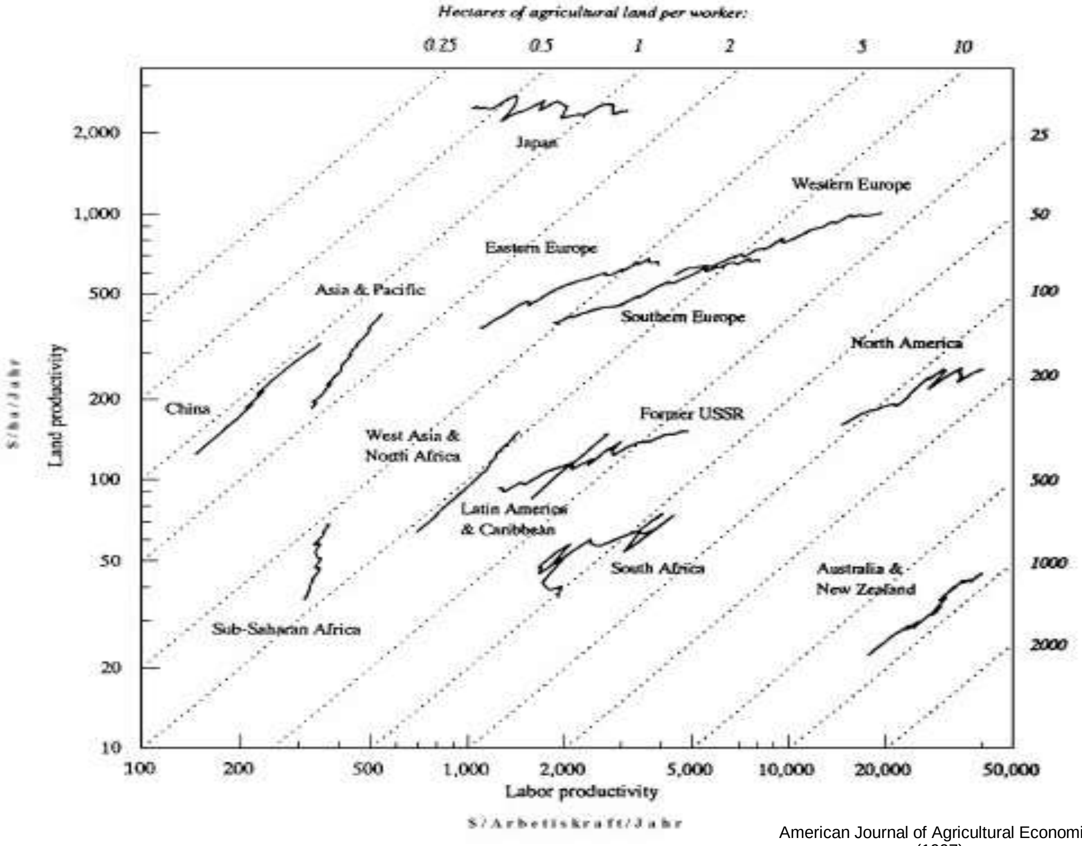
Any student who enters a course in the physical sciences soon comes across the concept of efficiency. One of the first things we learned in high school physics (given the state of education today, one may now have to wait until college) is that efficiency is a measure of the success achieved relative to the effort expended. Quantitatively, it is simply the ratio of output to the input. The fraction of what goes in as raw materials or energy that ends up as useful product. Engineers, being more mathematically inclined, often define it as the ratio of two ratios: actual mechanical advantage over ideal mechanical advantage – but it amounts to the same thing since the denominators cancel out.

And chemists are even more sophisticated. They know how to define the efficiency of a process at several different levels, depending on which of nature's limits is operating in the process. These limits are described by the three laws of thermodynamics. So, a process may be very efficient under the 1st Law of Thermodynamics, but may not be at all efficient under the 2nd Law. Cooking with electricity is a prime example of this: a cooking range is extremely efficient for transferring heat to the cooking pot but making electricity in the first place is a highly inefficient process. Thus, this is not a good way to use electricity which has many other possible uses that are far more valuable, such as running machines, separating chemical substances or even lighting.

For those of you who are not familiar with the three laws of thermodynamics, you may well have encountered their equivalents outside the classroom: they are, in fact, no different from the three well-known laws of the casino:

- First Law of the Casino: You can't win
- Second Law of the Casino: You can't even break even
- Third Law of the Casino: You can't ever get out of the game

The most important point to remember about efficiency is that it is not an abstract, absolute thing. Efficiency is measured in terms of a given input, and for the same product or output, it can be, and often is, different for different inputs: land, labour, resources, knowledge, capital. Look at the chart below, taken from a 1997 issue of the American Journal of Agricultural Economics. It shows that the agricultural systems adopted by the Japanese are as different from those in North America or Australia as day is from night. One maximises the productivity of land (which in Japan is scarce and every farmer has an acre or so) and the other maximises the productivity of labour (which in America and Australia is very expensive and every farm worker has a thousand times more than in Japan). Which, in your opinion is "better"?



American Journal of Agricultural Economics (1997)

Efficiency in the real world

Economics has sometimes been called the "dismal science". Dismal yes, particularly from the point of view of the poor and the marginalised; but science? – a lot of people might consider that a bit of an exaggeration. I think economics could be better described as the (almost ruthless, and not always salutary) "pursuit of efficiency at the expense of all else". Economists like markets because they are "efficient". Any first year economics textbook will tell you that "Allocative efficiency is the market condition whereby resources are allocated in a way that maximises the net benefit attained through their use." At this point, at which supply meets demand, the market is ticking over with maximum efficiency.

"Allocative" is not to be confused with "distributive". The term allocative is used by economists primarily to refer to the sharing of raw materials and inputs (including the various factors of production, land, natural resources, labour, knowledge and capital) to the productive processes of the economy. Its meaning subsumes the concept of efficiency. The latter term, distributive, on the other hand, refers to the sharing of the output among different segments of the population, at the consumption end, and has elements of fairness and "distributive justice" associated with it. These two seemingly identical concepts are, in the mind of the economist, actually completely distinct – though even they often confuse them and get them mixed up.

Adam Smith's specialisation and David Ricardo's comparative advantage were simply tools to achieve greater efficiency – in production. Markets may be no good for equity or social justice or the environment but because they do tend to promote some degree of efficiency in the allocation of resources to different uses, they are the favourite mechanism of the economics profession. In this respect, incidentally, Karl Marx was no different from the classical economists: he simply wanted to assert the primacy of labour over capital in deciding who gets the benefits of the production system and therefore, in the longer run, has the purchasing power as a consumer.

Pareto introduced some rigour into this relationship by defining the most efficient economic option as the one for which no one can be made better off without making someone else worse off. Kaldor and Hicks broadened the scope of such optimality by including those who would be willing to accept compensation for not being better off from those who do become better off, thus establishing a net benefit for society as a whole.

But John Maynard Keynes understood that markets can fail and studied the conditions under which the economy settles down to less than complete use of its resources (labor, capital, natural resources, etc.) because of inadequate aggregate demand. Such conditions prevent the economy from working at full efficiency and can be responsible for large scale unemployment co-existing with less than the full output it is capable of.

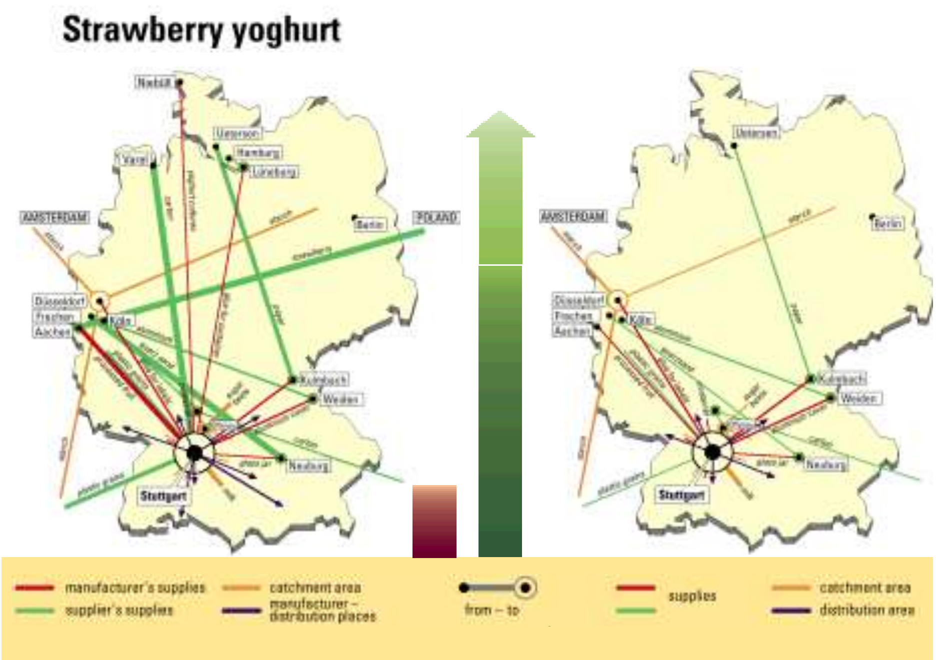
Another type of efficiency measure proposed by the Harvard economist Harvey Leibenstein concerns itself with the fraction of ideal production a firm actually puts out. He found a wide variety of limiting factors, including the motivation of entrepreneurs, the work ethic of the employees and defined a new concept, X-efficiency to describe this type of inefficiency, which he attributed to lack of competitive forces. The central goal of neo-classical economics and modern economic theory, competitiveness, is actually just another term for efficiency. Competition and efficiency go together.

For businesspersons, efficiency and competitiveness is all about cutting costs and maximising profits. The most profitable company is the most efficient. And vice versa. In a perfect market, this means that the resources, processes and innovation in the firm are being managed in a manner that cannot be improved in terms of profitability. Such profitability guarantees that the firm has been able to manage its ability to supply things in sufficient quantity to meet demand (a good part of which it may have created and manipulated through clever advertising and marketing methods). But it has little to do with efficiency in real terms – in terms of meeting people's felt needs with the resources available on this planet.

Efficiency with less than full cost accounting

The trouble is that neither the economist nor the business person wishes to acknowledge the real costs of their inputs and outputs. It is the prices they face in the market that determines their decisions. Not the *full* costs as ecologists would call them or the actual costs as any ordinary housewife would easily recognise them.

A story that illustrates the enormous gap between how engineers, economists and business people see efficiency and how scientists, ecologists and environmentalists see it is exemplified by the carton of strawberry yoghurt, which as many of you know, is the favourite breakfast food in Germany. A colleague at the Wuppertal Institute in Germany decided, as a part of her research on the efficiency of the current production and distribution systems, to follow the movements of this product starting from the dairy where the milk for the dahi originated to its destination in a small carton on the breakfast table. The journey ended up taking her all over the continent of Europe. The carton of strawberry yogurt actually arrives on that breakfast table after its ingredients have made a journey of some 4,500 kilometres. In addition, the suppliers' inputs had already travelled 3,500 kilometres. That is a movement of some 8,000 kilometres, in a country that is not short of milk and strawberries of its own. The milk for the strawberry yoghurt carton starts from a dairy perhaps in Holland or Belgium and is taken, I believe, to France (where they are good at making wines, cheeses and other fermented things) to be converted into yoghurt. From there, it is trucked to Germany and on to Poland, which is where the cheapest strawberries are available. And the entire package is then trucked all the way to Budapest in Hungary for printing the label presumably because the ink is cheaper there. And then it is trucked all the way back to Frankfurt – and Stuttgart and Zurich, etc – by autobahn. I think that Italy was also on the route, but don't recall precisely what they added to the product. Clearly, all this makes eminent sense from the point of view of the business. (Otherwise, why would they do it?) This may well be the least cost and therefore the most "efficient" way to deliver a breakfast food to a home in Germany, given the prices that are actually paid for the raw materials, fuel and infrastructure use. But for nature it is a disaster. And the reason, of course, is that the prices paid for energy, transport and other services are hugely subsidised. The environment actually pays the bulk of the real cost (by absorbing pollution, acid rain, deforestation, floods and other societal costs). Society pays some in accepting noise, congestion, accidents and loss of various amenities. And governments pay the rest (through subventions that help to underprice and therefore promote over utilization of the resources). The autobahns, like our roads; the petrol, like our fuels, the fertilisers and pesticides for the strawberries, like our own chemical inputs are all sold at prices that do not take account of the devastation, depletion and pollution of our natural resources, nor of the exploitative wages paid for labour. Here is the map of travelling ingredients from the Wuppertal research:



You may well say that this story reflects the grossly distorted pricing structure of transportation and energy in Europe. What does it have to do with India? Well, quite a lot, really. For one thing, our prices are far more distorted than those in Europe and the costs of ecosystem services are even less well integrated into them. Secondly, we have the same mindset problem, only worse since we have not had the time to observe the impacts of such a market. Let me give you an example of such a mindset. My company designs high efficiency chulhas (woodstoves) for use by village housewives. The chulhas are designed to be manufactured locally, close to the point of sale to minimise costs and to create jobs and local capacity at the same time. I was seriously advised by a former CEO of a major multinational FMCG that this was a bad mistake and that the only successful strategy would be to make the product in a centralised facility and deliver it by truck all over the country, "just like soap". He said that the business of business is to make money and not to worry about issues such as environmental protection, employment generation or the national good. My discussions with other captains of industry suggest that – with a few notable exceptions – this is not an isolated view, which means that the more "efficient" they are the more destruction of our natural systems we can expect.

The long journey from what is to what would be possible

From the point of view of long-term sustainability, efficiency is not a single, unambiguous measure that everyone can subscribe to and accept without reservation. In fact it has numerous levels and many sublevels within these levels that make it not just hugely complex but close to unusable as a means of societal choice, let alone communication. For this reason, the science of cybernetics has tried to categorise the concept of efficiency into three broad groups:

- **Rated Efficiency**, as normally defined and measured -- the actual outputs compared with the outputs that are considered possible within the framework of the given system, that is to say without any significant changes or investment to improve the system; in other words, *what is the output?*
- **Potential Efficiency**, which is the ratio of actual output to the output that should be expected if superficial – or even deep -- improvements were to be made in the system involving minor investment; in other words, *what should be the output?*
- **Latent Efficiency**, which is the ratio of actual output to the outputs that could be obtained if structural changes were to be made to the system – including changes in strategy, technology, approach to fulfil the same overall goals; in other words, *what could be the outcome?*

I believe there is an important fourth category as well:

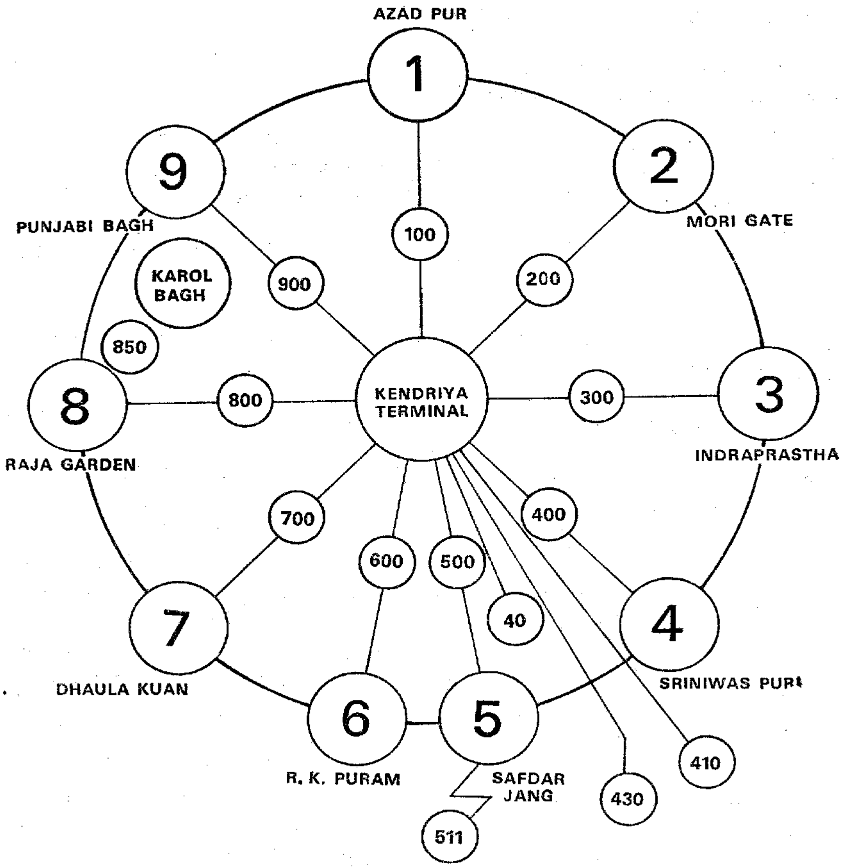
- **Systemic Efficiency,** which is another quantum jump in reducing inputs but involves changing outputs and the basis of satisfaction – a paradigm shift; in other words, *what would be the impact, if…?*

In the coming decade, I believe that we will increasingly find it necessary to inject an ethical dimension into our understanding of efficiency – efficiency with a commitment to human solidarity, efficiency for a better world, efficiency to nurture all life on earth. Such efficiency will have to come in from both sides: improved productivity and reduced demand, particularly for the material inputs provided by nature.

In many systems that I have come across, the rated efficiency is pretty low, the potential efficiency is very low and the latency is abysmal. Systemic efficiency needs an entirely different way of thinking. An example, which I will discuss a little later, is "demand side management" (DSM), applicable to the cheaper delivery of many utilities and public services such as water, electricity, energy, transport, communication, etc.

But let me give you a more specific example from a systems optimisation I undertook some 30 years ago. You will recall that because of the Six Day War in the Middle East, and the coming into its own of OPEC, the price of petrol suddenly shot up at the end of 1973. I was then working as the director of the Division of Environment in the Ministry of Science and Technology. It occurred to me one night that the bus system of Delhi, which then had some 2,500 buses on the city's routes and carried, if I recall correctly, some 1.5 million passengers per day, could be better designed and should be able to carry a far greater number of passengers if some basic changes were made in the routes and frequencies of the services. The trouble, as I saw it, was that the Delhi Transport Corporation had routes that had grown in a haphazard way over the years and wound and wove their way from one end of the city through all kinds of twists and turns to the other end. The implicit objective of the routing was to provide as many direct origin-destination connections so that passengers could get to where they were going without having to change buses. Under such circumstances, it was understandable that they measured the efficiency of the system basically in terms of the number of passenger-miles carried (and of course fares collected). But this did not give DTC's management any particular insight into what potential or latency there existed for efficiency improvements. Their routes and services responded to the origin-destination data, which in turn were collected in the framework of the existing system. So the question of making any fundamental changes in the system never surfaced.

I was able to persuade DTC to try a whole new approach to running its buses. We set up a hub and spoke system, with a crucial ring road service. The key was to maintain the highest possible speeds and the maximum possible frequencies – the ring road service, in both clockwise and counter clockwise directions was running as much as one bus every two or three minutes. In this system, it was essential to take long-distance commuters on express, non-stop buses, instead of tying up their time and that of the bus (which was the scarce resource) stopping every few hundred meters letting off and picking up passengers. The local routes would then provide them last mile connections from the main, fast, non-stop routes. The system was designed to ensure rapid changeovers and give commuters many choices, encouraging them to take a bus going in the right direction rather than to exactly the right place. We don't have the time to go into the details but I can tell you that within three months, without adding a single new bus, we were carrying more than double the number of passengers. In other words, we had released a hidden capacity in the buses of more than 100%. This capacity was in the potential category, because we simply arranged things so as to get the passengers out of their seats and out of the buses in less than half the time. This meant that the bus could make twice as many trips per day, essentially doubling its capacity.



In terms of the earlier paradigm, the capacity utilisation (another facet of efficiency) was pretty high – in fact more than 100%, as was evidenced by the number of passengers hanging on to the bus from all sides. In terms of the new routing-scheduling system, it was less than a 50%. This is the meaning of potential efficiency. The then General Manager of DTC, Mr SK Sharma, with whom I am still privileged to work closely, and I went on to explore even higher realms of efficiency – what I have earlier called latent efficiency – by a wide variety of debottlenecking exercises, such as introducing dozens of bus depots to provide the much higher level of maintenance needed for buses that were now doing twice the mileage, bus interchange nodes and bays for bus stops, one-way streets, improved bus designs for quicker passenger movement and fare structures to encourage passengers to take quicker routes, even if they covered longer distances and other measures. These involved some, though not very large investments and made it possible for DTC to carry even larger number of passenger-miles. Possibilities for systemic efficiency improvements will come from improved communication systems (already happening), courier services, location of residential and work facilities, and progressively higher level interventions.

Putting our underutilised assets to work

Our world is full of underutilised resources. School buildings that are used only 30% of the time, or 50% of daylight hours. Automobiles that in terms of passenger seat available are used less than 1% of their capacity. And government offices that in any meaningful sense are hardly ever used at all. How does one measure the possible improvements in efficiency of utilisation for such assets? Is it in terms of their potential – or latency? For grossly underutilised resources, the two concepts tend, of course, to merge somewhat. And one can go even beyond latency – by reducing demand for the services. Whether it is for electrical power, or water or transport or any other public service it is possible to go to very high levels of productivity indeed by reorienting society's behaviour so as to get greater satisfaction while using less.

Even more interesting is the question of how efficiency and sustainability relate to each other. We find it easy to ask how efficient a given process or activity is. But I have very rarely heard it asked how sufficient is it to fulfil human or societal needs? Sustainability, sufficiency, efficiency … the relationships among these concepts will determine whether this planet is a liveable place for our children and certainly much harder choices will have to be made within the lifetimes of their children if they are to have lives that are even remotely secure and sustainable. This means that efficiency per se, without reference to the larger goals of society is not a meaningful concept. Chasing efficiency for the sake of efficiency can be extremely dangerous. Remember Hitler's Germany had the most efficient military-industrial apparatus of all time.

The question of sustainability is not a minor one. With every economic activity, we move various resources, often in large quantities, sometimes over very long distances. These become not just the raw materials for our industrial engine but also wastes and pollutants that poison our land, water and air. Today, anthropogenic movements of solid materials at the Earth's surface are or of a magnitude that is approaching those of geophysical flows. Within a century or two, humankind is introducing perturbations into nature of a size that it took nature billions of years to co-evolve with and adjust to. This is not a trend that one can view with equanimity.

Factor 10 tomorrow

With each product or service, comes an "ecological rucksack" of associated material flows that is invisible but often huge. Take that gold ring you are wearing. Assuming it weighs 10 grams, its rucksack weighs 540 tons -- material that was dug, sifted, moved and purified to get the finished product to you. The rucksacks for other products or services are

1 ton of plastic	6 t
1 ton of steel	7 t
1 ton of paper	15 t
1 ton of aluminium	85 t
1 ton of copper	500 t
1 ton of platinum	320300 t

But it is not just materials and metals that have ecological rucksacks. Take a look at some of the other ones, just in terms of the water they use per Kg of product:

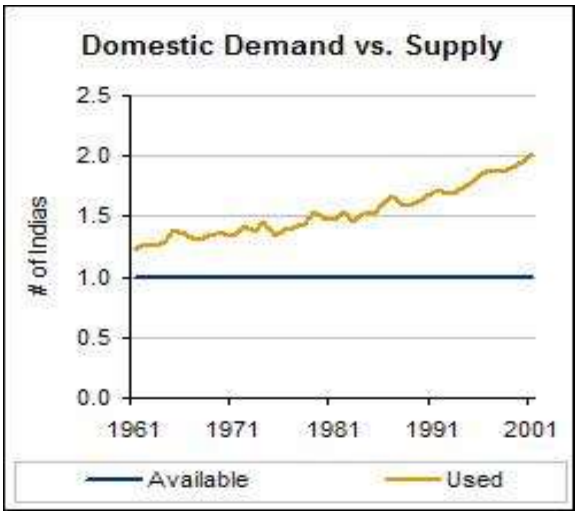
1 litre of orange juice	22 l
1 kg of wheat:	1000 l
1 kg of rice:	2000 l
1 kg of beef:	5000 l

1 kg of finished cotton:	40000 l

Each of these products has, of course, many other requirements in addition to water. The litre of orange juice needs, for example 1 square metre of land to grow the fruit plus 0.5 litres of fuel to process and transport it. This does not include the resource costs of packaging, marketing or buying it.

Some twelve years back, recognising the deadly forces at work against nature that were accumulating all over the world and the threats they posed to our planet's life support systems, several of my international colleagues and I set up the Factor 10 Club. With the German scientist Bio Schmidt-Bleek taking the lead role, this initiative has been instrumental in developing many of the insights needed to deal with the problems looming ahead. To get some idea of how environmentally destructive a product is, we calculate its material intensity, i.e., the inverse of its resource productivity, the Material Inputs per Service unit (MIPS). For most modern industrial and agricultural production processes, the MIPS is extremely, and unnecessarily high. According to various studies and estimates made by our group, the total material flows worldwide are already beyond what is sustainable in the long run and must be brought down by at least one-half. If the people of the Third World are to be left ecological and economic space to bring the quality of their lives up to the rest of the world, then the people of the industrialised countries will have to reduce their material consumption by a Factor of at least 10. Factor 10 thinking has gradually permeated into both policy and research levels, and even among some corporates. It has been formally adopted by the government of Austria and underlies the sustainability policies of Japan and, now, of the European Union.

Other people feel more comfortable with the concept of the "ecological footprint", which is another way to express the same concerns. The footprint of an individual, community, nation or the world is the area of land required to support their resource needs. The size of the footprint does, of course, depend on the kinds of expectations one has of what is an acceptable quality of life. We in India may well be willing to live with less, in which case our footprint would be accordingly smaller. But making some simple assumptions allows us to compare the impact our lifestyles (multiplied, of course, by our numbers) has with those of others. The footprint for the whole world is currently estimated to be approximately 1.2 planets the size of Earth and is expected to rise to about 3 by the year 2030. The footprint for India is already running at about 2.1, according to the same methods of calculation.



It is a national characteristic of ours that we will spend our time quibbling with anything that is unpleasant or inconvenient. No doubt there will be people who reject the concept of ecological footprint, saying that is flawed and too western in its definition – like all the other indexes where we come in at around 150th position in a list of 200 countries, just above Chad and/or Cambodia. We have spent the last fifty years rejecting a lot of indicators because the reality they portrayed did not fit our self-image instead of getting on with the job of making our nation a better place for all. But in any case, even if the ecological footprint is, let us say, overestimated by a factor of 2 and is actually at the moment only around 1, the prognosis for our children is not good.

Factor 4 today

Where Factor 10 reflects the "latent" improvement that must be made in resource productivity, then Factor 4 represents the "potential" improvements that must, and by definition, can be made. This means that with current technologies and minor changes in our production and distribution systems, a doubling of wealth can be achieved while halving the quantity of resources that are used. Professor Ernst von Weizsaecker in Germany and his collaborators, have collected numerous examples of how this is possible and have written a wonderful book on how it is already being done in many different contexts.

You may well say that all these resource conservation issues are relevant for the rich countries but are just conversation for the poor ones like us. We need to create much more wealth before we can start worrying about saving resources. Unfortunately, there is a huge fallacy in that argument. Certainly, we need to improve the lives of a huge number of our fellow citizens, each by a huge amount. As fast as possible. But this does not mean that we can be cavalier about the resources nature has given us to make this possible. The fact that India's footprint is already twice the size of the country and twice the global average means that it is even more important for us than for others to find better, more resource conserving ways to satisfy people's needs. This requires much higher resource productivity than is available through the technologies and production systems that we are buying or copying from the richer countries. Factor 10 does not mean slowing down the "development" of our economy but rather to choose a different path to make secure, safe and fulfilling lives for all using far less material and energy resources.

The centrality of resource productivity

Over the past two hundred years, economists have focused their attention (after the classical economists) on the productivity of capital and (after Karl Marx) on the productivity of labour. But they have never really looked at the efficient utilisation of the third factor of production (which they termed "land" but is actually more correctly natural resources) as being worthy of their interest. It is this factor which is rapidly becoming a major constraint in our production systems, by imposing its limits, either as a resource or as a sink. The key to sustainable industry, as to sustainable agriculture lies in improving the resource productivity of our techniques and methods.

To do this, we will have to rely on a combination of market based and regulatory instruments. By removing unnecessary subsidies, the markets can be helped to give more accurate pricing signals. By putting in place policies that encourage internalisation of all costs and taking the longer view, production systems can be enabled to organise themselves to fulfil private goals without jeopardising the public good. And to do this, needs extremely effective information systems, providing quasi-real time data on economic and ecological parameters so that the businesses can make informed decisions.

One of the reasons why we have ended up with such deep systemic problems is that the professionals who design our solutions have been training to think narrowly and reductionistically. For each type of societal need, they have only limited number of responses to draw from. And that just isn't enough. Unless we think out of the box, we will go on having the same old solutions leading to the same old problems.

Engineering with a biologist on the Team

Let us look at how New York City dealt with its water supply problem. Because of the growth of population and industry, the City decided some years back that it had to augment its drinking water supplies. The engineers and economists happily came up with a design for a water treatment plant with all the primary, secondary and tertiary facilities, tanks, pipes, pumps and the whole lot of engineering paraphernalia. The capital investment was estimated at 6.5 billion dollars, with a 300 million annual operational cost. Then someone – no doubt an NGO -- suggested that it might be cheaper and more effective to rejuvenate and clean up the catchment area in the Catskill Mountains north of the City and improve the quality of the water coming in, so it would not need as much treatment. As it turned out, upstream catchment area could be carried out at a total cost of 700 million dollars, and not only would not require annual operational upkeep but would generate more than enough tourist dollars to pay for the investment over a few years. That is what one could call a truly win-win situation: getting better water and making a savings of some 6 billion dollars – all at the same time!

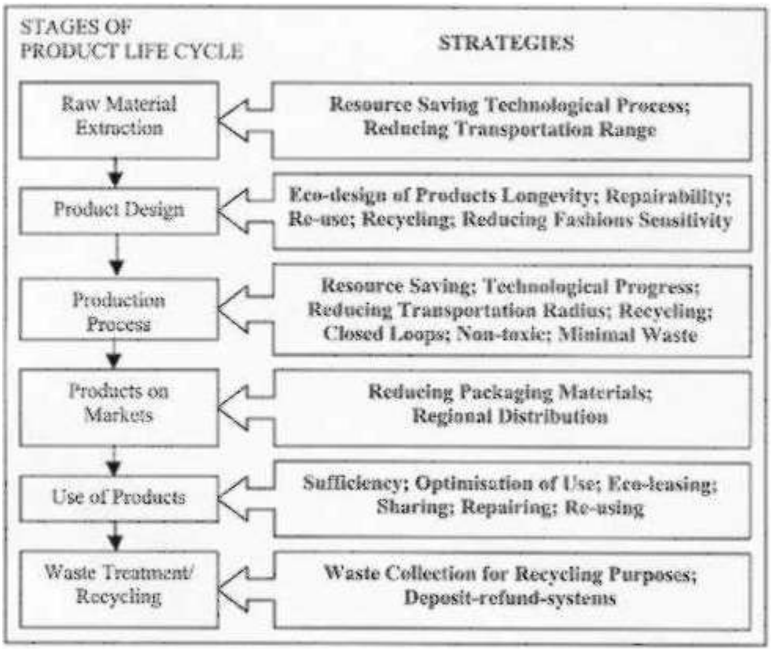
Which option do you think the city managers wanted to opt for? And which one do you think the citizens voted for?

But embedded right in that little story is another one that is one of the keys to dealing with the health and security of our ecosystems. And this is that we need to bring biology back into our engineering. By using the 5 Kingdoms of nature – animals, plants, fungi, algae and bacteria – together, it is possible to bring about vast improvements in resource efficiency, as the coffee growers in Columbia found out with combining coffee growing with mushroom cultivation. The wastes of one activity became the inputs for the other.

The lesson we quickly learn is that life is not as simple as our professionals make it out to be and whenever we need to optimise something like efficiency, the optimisation has to satisfy several different objectives at the same time. More complicated than that is the fact that efficiency is itself only one of several other objectives such as equity, environment, employment and empowerment that need also to be satisfied and if the market is not geared to dealing with these, then someone else has to be prepared to do so – government, civil society, social enterprise, whoever feels responsible.

Lifecycle Analysis

For transportation systems the range of objectives to be met simultaneously includes speed (time of transit), cost, convenience, safety in addition to capital servicing and profitability. That is why any good national transportation system needs a mix of modes ranging from road, rail, river and coastal shipping, aircraft and airships. For household appliances, the resource productivity criteria include durability, lifecycle cost, reliability and maintainability in addition to the marketing pluses of convenience, safety, styling, etc. A Wuppertal Institute report describes the kinds of methods available to improve resource productivity:



What becomes quickly obvious in multi-objective, non-linear situations such as the ones we have to deal with every day, the interventions needed are not always the obvious ones. Equitable and environmentally sustainable development is inherently a goal of considerable complexity and only systems like the marketplace can handle the kind of information needed to make them work. But not any old laissez-faire marketplace but one which has built into it the regulatory and societal checks and balances that ensure widespread delivery of the benefits of economic progress, now and for future generations. 50 years of international development, with more than 1 Trillion dollars of so-called aid and more than 5 Trillion dollars of international trade have still left half the people on this planet below a poverty line of $2 per day. Large, centralised industry, supported by large, centralised infrastructure, and lubricated by large, centralised financing is not going to change this in the time scale that is acceptable.

The next steps

The obstacles to bringing about a more efficient and sustainable development are many. Vested interests – among business, governments and others – are very strong and will continue to resist changes that reduce their positions of advantage. Speedy delivery of government and judicial services is crucial but strongly (and effectively) resisted: the former by both politicians and bureaucrats and the latter by the lawyers and other professionals who benefit from the rental opportunities created by slow decision processes.

It is difficult to make good decisions with bad information. While much of the kind of data I have referred to is easily available for OECD countries, it is non existent for most developing country economies. Much of the research needed is technical understanding of the actual services that the ecosystem provides and the costs of finding engineering-based substitutes for these. We also need to develop new technologies that are of little interest to the research institutions of industrialised countries since the relative prices of their factors of production (land, resources, labour, knowledge and capital) are so different from ours. A clearer understanding of the subsidies paid for certain activities (particularly energy, water, transport, agriculture and international marketing) would help in making more rational decisions.

Policy interventions are needed through regulatory and fiscal measures to ensure that the long term interest of the nation is not jeopardised by short sighted behaviour on the part of actors in the polity or the marketplace. In particular, incentives need to be set in place to encourage the decentralisation of production facilities in those areas where these are appropriate, manufacture of durable products, substitution of non-renewables by renewables and adoption of resource efficiency measures wherever possible.

Build the capacity of the private sector and civil society to undertake detailed studies geared at generating better options for resource productivity increases. Since much of the economic activity will have to be in the mini and small scale sectors, establish effective services to provide technical, marketing, financing and other supports needed by them to become viable and sustainable.

None of this can happen without a professional ethic. The kind of ethic that Dr P.R. Srinivasan exemplified in his personal and professional life is a basic pre-requisite if the advice we are to give our clients – be they in the private sector or government – is to be first and foremost in the interest of society as a whole.

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