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Keywords

History of technology, technology assessment, social transitions, needs and wants

Abstract

This essay is a result of many years of thinking about the role of technology in human life and about the ways in which new technologies develop. It may be viewed in two ways: either as a history of technology since earliest times to the present, with emphasis on ways in which technology interacted with society, or alternatively some may read it as a description of technology in a social context, illustrated by examples from the history of technology. Whereas in early times technology served in the main only to support, indeed enable, human life, it later became a major economic factor and the chief creator of wealth. New technologies arise when a technological idea – whether based on new scientific phenomena or not – appears to offer promise for commercial success. A technological innovation happens if and when there is a confluence of a technical possibility with the promise of a profitable market. Technology now permeates all spheres of human life, for better or for worse, and dominates the real economy. I think that much of technology is for the better, but we have to be very careful about many abuses of the natural environment and many other misuses of our technical prowess. The argument is not hostile to technology, but takes a critical view of it. We are too profligate in our use of natural resources and we often forget human values in our uncritical indulgence in astonishing technological capabilities. The book „From Need to Greed" which underlies this essay addresses the lay reader, though I hope that many professional technologists and scientists will find in it much of interest.

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A much more detailed treatment of the same material can be found in the book by Ernest Braun, 2010, From Need to Greed, *Vienna: Austrian Academy of Sciences Press.*
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1 The History of Technology in Society

Technology is almost as old as humankind. Humans, unlike animals, do not accept circumstances as they find them, but try to alter circumstances in their own favour. The production of useful artefacts – technology – may be regarded as the very essence of human nature and human activities. For thousands of years technology remained very simple and the small groups of stone-age humans lived a nomadic life as hunters and gatherers. Gradually humans learned to shape natural objects into useful tools. They learned to sharpen spears and to shape stones into a variety of cutting, scraping and digging tools. Making tools was not a specialized activity at first; tools were made by those who wanted to use them. Over the millennia the production of tools improved and new types of humans, essentially new species, emerged in a slow succession, replacing each other right up to the emergence of homo sapiens, modern human, who became the sole human species some 30,000 years ago.

1.1 Ancient History

Science distinguishes different stone-age periods by the tool-making techniques used. The gradual improvements in techniques led to a gradual growth in populations by securing a higher survival rate and an extended life-span. The increased population led to more exchanges between humans, and thus to improved learning, and thereby to an acceleration in the rate of improvement in living conditions.

A major change in human life occurred in the Neolithic period, roughly from 9500BC, and the following metal periods from about the 4th millennium BC, when humans learned to plant and harvest crops and settled in more or less permanent settlements. When they also managed to domesticate animals, their dependence on hunting and gathering was broken and the nomads gradually became settled peasants. The development of settled communities had far-reaching consequences; some obvious some less so. Among the less obvious consequences was an acceleration in the rate of improvement in technology. Knowledge became shared knowledge and shared knowledge improves and expands much faster than knowledge based purely on individuals. Most of what we know we learn from others; single individuals invent or discover very little by themselves.

Perhaps the most fundamental concept of community life came about with the establishment of agriculture and permanent human settlements: the concept of wealth. Nomads own only what they carry with them and early nomadic hunters and gatherers owned practically nothing. With the rise of farming, however, land and domesticated animals became valuable and the ownership of land, in whatever form of organization, represented wealth. The sedentary life opened up further opportunities for the creation and ownership of wealth. Houses and domestic equipment became wealth, livestock and agricultural implements became wealth, food surpluses became wealth. With the growth of towns human society became organized in larger units and increasing efficiency of food production led to a division of labour. It was no longer necessary to produce food yourself if you wanted to eat, it became possible to fulfil other social tasks and be fed with food produced by farmers. Increasing agricultural production created new needs for technology to satisfy – agricultural implements, irrigation systems, transport and storage facilities had to be created and steadily improved.

I regard the change from a nomadic existence to a settled existence and the establishment of the concept of ownership and wealth as the first major transition brought about by technological development. Technology developed the possibility of local food production to replace roaming and searching for food and thereby caused the change from scattered nomadic communities to fixed human settlements. This was the first tentative step on the way to modern society.

With the growth in the variety of human activities, the number of different technological artefacts increased. Individuals were no longer able to produce all the tools they needed. The increasing variety of technologies included new agricultural implements, such as the plough; horses and cattle were domesticated and were used as draught animals, which meant that wheels and carts had to be produced to transport agricultural produce into the cities. The biggest cities were built near rivers and the rivers made it possible to irrigate the fields, thus increasing their yields of food crops. Irrigation systems were built to increase food supplies, and the food was stored in store-houses to feed the growing populations in growing communities. As communities grew, the number and complexity of buildings also grew and it became necessary to provide water supplies and sewerage for these growing towns.

With increasing wealth, it became possible to satisfy desires for exotic goods through imports, especially spices and jewellery. This gave rise to international trade, but internal trade also developed because different regions were able to produce different goods. Thus one of the newly created occupations was trade and some traders became prosperous and influential.

Throughout this period, lasting many thousands of years, technology developed by satisfying new needs. Needs and the possibility of satisfying them grew together, hand in hand, as it were. Technology satisfied needs and technological possibilities helped to create needs. The idea that it might be possible to become rich by inventing new technologies did not occur to people until much later. Technologies were at first developed in order to survive, albeit barely, and later technologies were developed to enable more people to survive a little more comfortably. Food became better and more plentiful, shelter improved; the need to migrate was eliminated. Last, but not least, communities developed and with them interchange of technological and social ideas.

One of the most spectacular early results of the rise of communities were the great monuments, such as Stone Henge and many more. We can only speculate why these great structures were built; possibly as religious manifestations and for mass worship, or possibly for community ceremonials, and certainly also for burials. What is very clear is that with only very simple tools available, the human effort in building these vast monuments was enormous. To organize and coordinate such effort, some form of organization was needed that probably involved a whole region rather than just individual settlements. Huge stones were transported over considerable distances, probably by rolling them on logs, and large quantities of earth were shifted with antlers serving as shovels. We can only speculate on the need these monuments served, but we can be sure that they served a need and were not motivated by greed. Even at this early stage humans developed spiritual needs that were taken as seriously as material needs and both could be satisfied with the aid of technology.

Over time, technology became more complex and the production of technological artefacts was gradually taken over by specialists. The development of society brought with it the creation of new occupations. To name but a few in addition to craftsmen, we may mention administrators, merchants, soldiers, builders, rulers, priests. Each group had its own opportunities for owning wealth but some individuals and groups had more opportunities than others. Almost as soon as the concept of wealth became established, differences in wealth arose and the accumulation of wealth became an important human goal and has retained or increased its importance to this day. Technology, however, was only indirectly involved in creating wealth. The idea that technology might be used directly as a creator of wealth came much later.

Another landmark development in human history was the discovery of metals and their uses. Copper and more especially bronze tools were considerably more effective than stone tools and when iron smelting was developed, the efficacy of tools and weapons increased by leaps and bounds. Another line in the development of metals was the discovery of precious metals, particularly silver and gold. As society became stratified, the rich and mighty developed a taste for ornaments and, for preference, ornaments made of precious metals because of their durability and lustre. Precious metals could be acquired by trade, but they could also be stolen from neighbours in raids and wars. Wars became even more desirable as slavery became established. In wars women could be stolen to replenish the stock of available women. Adversaries of both sexes could be brought home as slaves. Prisoners of war became the property of the conqueror and became an important source of almost free labour. When adequate food could be produced without everybody producing it, wisdom no longer demanded that prisoners should be killed or eaten. Humans were degraded into property with no rights and slavery prevailed for centuries until the development of machinery made it unprofitable.

Greed raised its ugly head as soon as towns began to grow and to be organized with some form of governance. The rulers and the ruling elites became greedy and took more than their fair share of local production for themselves. Armies were organized and equipped for the dual purpose of raiding foreign territories and protecting one's own territory against foreign raiders. Wars were not the result of need but the very epitome of greed. When successful, the victors stole goods, gained income from tributes, and enslaved prisoners. Weapons were needed for war and in this limited sense technology served a need, albeit a highly questionable one.

The development of early settlements eventually led to the growth of large cities and the early civilizations. Unhappily the term civilizations is a bit of a misnomer, because no sooner had humans formed into large groups, they got at each others throats. Early on weapons were developed for hunting, but the same weapons were soon used for killing perceived enemies. The fame of the early empires and their rulers rests not so much on their agriculture and their artistic achievements, but on their military prowess and conquering achievements. I would call the civic achievements civilization, and the military achievements barbarism. Those were the two faces of the coin known as civilizations. To my knowledge, the Indus Valley Civilization, which thrived in the Bronze Age period between 2600 and 1900 BC, was the only major civilization known for its advanced cities and art rather than for its military prowess. Perhaps this was the only ancient civilization worthy of the name civilization.

1.2 The Middle Ages

By the time of the Middle Ages, say from 800 to 1500 AD, technology had progressed to a stage that could sustain a population of Europe that fluctuated between an estimated 30 to 50 million, reaching a peak of 70 to 100 million in 1300 AD and declining considerably by 1500 owing mainly to the plague, famine, and war[1]. Many substantial cities had been built, and the human diet had improved considerably. Agricultural techniques developed considerably during the Middle Ages, in fact innovation in agriculture was the main thrust of medieval technology. The supply of useful artefacts had expanded enormously. Textiles, for example were produced in substantial quantities and good quality in cottage industries. A family might own a spinning wheel and/or a weaving loom and would produce cloth at home, working at their own pace. Bleaching was done by spreading

[1] http://en.wikipedia.org/wiki/Medieval_demography.

the cloth in sunlight and dyeing, if at all, with natural colours. A merchant would supply them with raw material, often wool but possibly also flax, and would buy their finished products.

Cottage industries provided a meagre income in return for long hours of work by all members of a family. If anybody did well out of this small-scale production of cloth it was the trader, though even that is uncertain. People worked in cottage industries to scrape a living, with no hope of becoming rich. The goods they supplied satisfied real needs, such as basic clothing, with perhaps a little extra, certainly not luxuries.

The production of cotton cloth started in Europe in the late Middle Ages. Over the years wool and flax were supplemented by cotton grown in American and other colonies. The pattern that evolved was to import cotton from the colonies to England and to produce cloth in Britain, exporting some of the finished cloth back to the colonies or other overseas countries. The consumption of cotton cloth in Britain also grew and indeed this was the very beginning of generally increasing consumption by all strata of society.

1.3 The Industrial Revolution

Two developments set the scene for the coming industrial revolution. Agricultural production became sufficiently efficient to feed large numbers of citizens who worked in a variety of tasks other than agriculture. The much-praised division of labour and diversification of products and services was made possible by efficient agricultural production. Thus labour became available for work in industry, as only a decreasing proportion of the workforce was needed to produce food. Potential industrial workers migrated in large numbers into the new industrial cities. The proportion of agricultural workers declined rapidly and today it is only a few percent of the working population in the advanced countries.

The second pre-condition for the growth of industrial production was a steady growth in the number of people who were able and willing to consume goods beyond the basic minimum. Industry provided goods that satisfied demand beyond the basic minimum needed to sustain life. Technology began to satisfy wants above and beyond basic needs. When surplus labour and surplus demand came together, the conditions for industrial production were fulfilled.

The true industrial revolution, however, required one more essential ingredient: skilled and imaginative craftsmen with a good knowledge of basic science who were able to invent and produce new machines of all kinds and, of equal importance, men of wealth who were prepared to abandon the security of investing in land and were willing to take risks and invest in machinery. Gifted inventors, backed by entrepreneurs, created a whole new system of production – the factory system.

The industrial revolution[2] changed everything. Men of genius, equipped with technical know-how and good scientific knowledge set about inventing machines that were capable of increasing production by leaps and bounds. They were driven by curiosity and technical ambition, but the wish to make money played much more than a secondary role.

Some further preconditions had to be met before the industrial revolution could get into its stride. A sufficient standard of technical capabilities had to be available. The art of metallurgy and of forming metal parts had achieved a sufficient standard and matters such as atmospheric pressure had been explored and understood by scientists.

[2] Say the period from 1760 to 1830, though some historians take a longer time span of 1750 to 1900.

The industrial revolution was the period when technology took its first steps toward satisfying greed instead of, or in addition to, need. The new technical entrepreneurs were in it for the money. They wanted to use new technologies to make money and indeed many of the new class of industrialists prospered and became wealthy. The industrial revolution resulted from a succession of inventions of production machinery, driven by a primary mover more reliable than the motion obtained from water wheels. The most important aspect of the industrial revolution was, however, the introduction of the factory system of production. The essence of the factory system is to produce as much as the market will take with the lowest possible input of factors of production, i.e. with the greatest possible efficiency. The workers have no autonomous control over their own activities. They simply do what management tells them to do, both in terms of the work process and of the timing of their activities. The worker, spinner or weaver or whatever, cannot use his/her skill; the knowledge of the work process is incorporated in the machines.

The primary process of the industrial revolution was the creation of a reliable source of power to drive machinery. Steam engines were to replace unreliable water wheels fed from small streams with irregular flows of water. Steam engines could be placed anywhere and thus enabled entrepreneurs to build their factories wherever they pleased, without regard to rivers or brooks. The first applications of steam power were not, however, its use as a primary mover for machinery, but as pumps for raising water, particularly from mines. The first relatively simple steam pump was invented by Thomas Savery, patented in 1698. Later Savery cooperated with John Newcomen to develop his engine in 1712. This pump used atmospheric pressure to perform the work whereas coal was used to produce steam to create the necessary vacuum.[3]

At this stage James Watt, generally falsely regarded as the inventor of the steam engine, began to dominate its development. Watt was an instrument maker at Glasgow University and forms the symbolic link between the old type of craftsmanship and modern science-based engineering. In 1764 he was repairing a model of a Newcomen engine and was struck by its inefficiency. He found the main cause of the problem in the fact that the steam, when it needed to be condensed, was condensed by cooling the whole massive cylinder of the engine, thus wasting a large amount of heat. The solution to this problem was obtained by adding a separate condenser, connected to the cylinder by a system of pipes and valves. This greatly increased the efficiency of the steam engine and formed the first of Watt's many major contributions to improving the steam engine and making it the main driving force of the industrial age, until it was replaced by the steam turbine, the internal combustion engine and the electric motor in the 20th century. Another famous invention of James Watt was the so-called „governor", that used the centrifugal force acting on two rotating weights to control the flow of steam into the cylinder of the steam engine and thus kept the engine running at a constant speed.

Watt entered into a partnership with an industrialist and went on to improve the steam engine as well as to manufacture and sell it. His partnership with Matthew Boulton, from 1775 to 1800, proved the most enduring and successful. About 500 Boulton and Watt engines were sold. With the availability of the steam engine as the primary mover for industry, industrial production truly came into its stride.

By the time of the industrial revolution, cotton had taken over as the main fibre for textile production. The first spinning machine, the „spinning jenny", was invented by James Hargreaves in 1766. A much improved spinning machine was invented by Richard Arkwright in 1769 and it was Ark-

[3] The enormous force that the atmosphere is able to exert was demonstrated in 1654 in a spectacular demonstration by Otto von Guericke in Magdeburg. A sphere was formed from two copper hemispheres and the air was evacuated from the sphere. Eight horses were unable to pull the hemispheres apart, though they were held together only by atmospheric pressure.

wright who first introduced the factory system, using his machines. By 1782 he was employing 5000 workers. The final word on spinning machines was spoken in 1779 by Samuel Crompton and his „mule". Alas, Crompton was cheated out of most of what should have been rightfully his, but the „mule" went from strength to strength. By 1812 there were 4,600000 mule spindles in operation.

With the introduction of the „mule", the spinning process had become highly efficient. The next weak link in textile production was the weaving process, and this was mechanized in due course. Edmund Cartwright introduced the power loom in 1785. In about 1789 steam began to replace water to drive the power looms. Hand weavers fought hard to retain their skills and their earnings, but the battle was hopeless and by 1850 nearly all weaving was done on power looms. By this time factories had taken over virtually all the production of textiles. The hand weavers and spinners and all the other cottage workers had been entirely driven out of business and suffered great hardship in the process. They tried to keep their foothold on textile production by accepting lower and lower earnings, accepting even starvation, but eventually lost the uneven battle. The industrial revolution gave birth to the working class and the protracted battle between weavers and industrialists was an early instance of class war.

The next feat of the steam engine was its application to transport. The two outstanding innovators in the field of steam-driven transport are George Stephenson as the main inventor of the steam-locomotive and Isambard Kingdom Brunel as the outstanding genius behind the building of railways and the first ocean-going steam-ships.

The social and economic impact of the railway was enormous. Railways were first built after a trial run on the route between Stockton and Darlington in Northern England, where in 1825 the *Locomotion,* designed by Stephenson, pulled the first ever passenger train at a speed of 24 km/h. This was the first step of a development that is continuing to this day.

Soon a veritable investment fever set in. Railway companies were formed, and had no difficulty in finding investors. When Brunel became chief engineer of one of the railway companies, the Great Western Railway, he personally designed many of the tracks, bridges and stations that function to this day. The mobility of citizens increased and tourism was virtually invented, requiring massive investment in hotels, piers and all the facilities that serve tourists. By increasing the capacity for transporting goods, the manufacturing industries became able to use their full capacities. Though some investors lost money on the railways, the total outcome was an enormous boost to the economy.

The railways caused a great deal of new employment and led to a growth in the working classes, as the building boom and construction boom and the operation of trains and points and all that required a large number of workers. What is perhaps less obvious is that directly or indirectly the railways gave employment to many middle class workers as well. We have mentioned the investors and entrepreneurs, but many more middle-class people were dependent on the railways. All grades of engineers were required, as well as accountants and lawyers and workers in tourism. The class structure of society was fundamentally changed, with many political repercussions, as the ranks of both the working class and the middle class increased in numbers and formed their political affiliations and organizations.

When the steam engine was used to drive ocean-going vessels, a development owing principally to Isambard Kingdom Brunel, overseas trade was greatly enhanced and parts of empires moved more closely together. Both railways and steamships were regarded as a blessing by the military because they facilitated far greater mobility for the troops. The railways caused a rather unexpected side-effect. Because of the need to create time-tables for trains travelling over long distances, it became necessary to create a standard time for the whole country. Whereas in the past each town had its own time, a standard time was now needed and moves to establish such a time started in 1840. In 1880 Greenwich Mean Time was finally established by law throughout the United Kingdom and rapidly spread throughout the world.

The repercussions of industrialization were multifarious and far-reaching. Factories were built, providing large-scale employment; new cities developed and old cities expanded to house the industrial workers; cities required a new, or greatly expanded, infrastructure including transport, food and other supplies, housing, educational and health facilities, police forces, water supplies, sewerage, paved streets, street lighting and so forth. More and more goods were manufactured and bought, thus increasing the consumption of goods of most members of society, albeit this consumption was very unevenly distributed.

2 Three Technology-Driven Transitions

In my view technology caused three major breaks, or transitions, in the development of human society. The first break was the development of agriculture and animal husbandry, causing a transition from nomadic hunting and gathering societies to sedentary societies. This first transition brought with it the concept of wealth and started the trajectory that led to the early civilizations, and to the development of religions, large modern armies and wars of conquest of colonies, and much inequality. Though technology certainly provided some luxuries, such as palaces for the rich and powerful, basically it provided only what people really needed. The vast majority of the population had nothing beyond basic necessities, though the definition of basic necessities changed and expanded with time and circumstances.

The second major transition was the industrial revolution, causing a change from small craft production to industrial production. The transition of industrialization elevated technology to the status of major provider of wealth – with the boom of investment in the railway networks it was realized that money could be made out of technology.

The third transformation is that to information society. Before we embark on discussing this shift, however, we shall to have a look at one of the major technological developments in the 20th century, namely the automobile.

The industrialization of textile production and the introduction of railways, with all their consequences, were soon followed by the invention and application of the internal combustion engine and the automobile. The very first automobiles were produced at the end of the 19th century, but the automobile is really a child of the 20th century. It was initially thought that only very few automobiles would be sold as toys for the rich. It became apparent however, that this view was entirely wrong. As automobiles became cheaper, more and more of them were sold and the infrastructure to make motor transport a major technological system was developed. Roads and bridges were built and surfaced, oil refineries were built and a search for oil reserves began, petrol stations were built and gradually a legal framework to regulate motor traffic was established. The risks associated with the motorcar soon became apparent, but rather than banning or severely restricting the car, an only moderately successful control system was developed and society became ready to put up with death and injuries caused by automobiles. As far as pollution was concerned, the automobile was hailed as the liberator from the gross pollution and stench caused by horse-drawn traffic in cities. The impact of motorization on large segments of the population is clear to see. People began to move into suburbs, suburban shopping centres were developed, traffic jams became a daily routine. Indeed the motorized bus in big cities is no faster than its horse-drawn predecessor.

The development of the production of motorcars followed a path that is familiar for newly established industries. At first a very large number of manufacturers joined the band-wagon and began producing cars. Gradually some of them found that the profitability of their business left a lot to be desired and gave up. The number of manufacturers decreased until today there are only very few very large producers left. Initially cars were built by hand in small numbers until Henry Ford introduced the conveyor belt and large-scale highly efficient production made the automobile a mass product.

The computer industry followed a similar pattern of development. At first a few computers were built using electronic valves. They were large machines using a lot of power and their reliability and performance was poor. It was thought that a few computers could satisfy all expected demand from the military who wanted them for calculating trajectories of artillery shells, and for statistical calculations, such as for census of population data. Then came the science-based engineering revolution of semiconductor electronics, the so-called chips[4]. The marriage between semiconductor electronics and computers was made in heaven. Chips are reliable, very small, and consume very little power. The first chips could perform very few operations, but their development over many years led to chips that are computers in their own right and form the core, the central processing unit, of all modern computers. The computer became ever smaller, ever more powerful and ever more affordable until it conquered a mass market and has become truly ubiquitous.

Beginning with the industrial revolution technology provided, and still provides, goods well beyond the level of basic needs, at least in the industrialized countries. I do not think that the change from mechanical industries with huge factories employing armies of workers to largely automated factories providing many technically advanced goods has changed these basic facts. What we may regard as a further transition is that from industry as the major employer to services as the major employers. Possibly of greater importance, however, is the rise of unfettered capitalism, so-called neoliberalism, which allows many people to become very wealthy, indeed without producing anything of substance or fulfilling anybody's needs. It is often said that we now live in a post-industrial age because industrial workers no longer form the majority of wage-earners. It is also said that we live in an information age because the production, manipulation and transmission of information has become a dominant economic activity and bankers, who are essentially manipulators of information, have become extremely greedy, rich and influential.

I think we are justified in calling the transformation from industrial society to an information society the third major transition in the fortunes of society, because the manipulation of information, in a variety of ways, has become a dominant economic activity. The combination of information technologies and unfettered capitalism has led to the creation of enormous personal wealth, simply by clever manipulations of information. Indeed, the successful capitalist depends on good information. The recent and still ongoing financial crisis illustrates the point. Information has become a commodity that can be traded and manipulated, creating enormous profits for the traders and manipulators. Some of the manipulations are in the nature of betting – hence the term „casino capitalism" – and it is well known that the bookmakers always make a profit at the expense of the punters.

The fact that modern factories are largely automated and require only small workforces is certainly very welcome to industrial managers and shareholders. The single or family owner has now been largely replaced by widely distributed ownership of shares. Shareholders are rather fickle and the running of corporations and factories is now largely in the hands of professional managers. The days of the ruthlessly exploiting owner are over, but so are the days of the paternalistic owner who cared for his workers.

[4] See e.g. Braun and Macdonald (1982).

Sales of technological products tend to stagnate. Consider the example of black and white television receivers. When they were first introduced they were expensive and the whole technological system of television was not fully developed. Gradually the system developed, receivers became cheap and sales boomed. Eventually almost every family had a television set and sales figures fell. The market became saturated and could be rekindled only by a technological innovation – colour television. Everybody wanted the new receivers, supplied with programmes by a new broadcasting technology. Today, colour television has become an old hat. In the meantime, three innovations have worked their way through the television market: flat screens replacing the bulky old sets, digital TV replacing analogue TV, and high definition television replacing the old standards in image quality. People have been obediently buying all these new goodies and the television industry could keep going so far. We may ask what next, but I do not know the answer to this question. All I know is that every attempt will be made by the industry to give an answer. This example describes a general pattern of sales. Sales for a new product rise and after a time stagnation sets in and sales begin to fall.

Producers of technology have a remedy for stagnating sales of their products – they substantially improve their product or bring entirely new ones onto the market. As old products become obsolescent and obsolete, they are replaced by new ones. More than that, new products can open up entirely new markets. Innovation keeps the economy going and is a major factor causing economic growth. Incidentally, where would Technology Assessment be without technological innovation? We know the impacts of old technologies, even if their analysis is often incomplete; what we need to assess are the likely social and economic effects of new technologies at an early stage of their development.

One means of stimulating markets is to add new features to obsolescent products. Mostly these features are pretty useless, but they make for good reading in the sales literature and they help to sell the goods. There are many examples for this phenomenon. Cars abound with new features, though it must be admitted that some of them improving safety or fuel economy are quite useful. Cameras or mobile phones bristle with features that most people are unable or unwilling to use, but they fulfil their function of selling the goods. Computers provide a plethora of examples. Each successive generation of computers offers greater speed, greater memory, and many other so-called improvements, yet the vast majority of private users of personal computers do not need even half the capabilities of these machines. I could extend the list, but I hope to have made the point that technical products are made for profit rather then for the satisfaction of real wants, let alone real needs.

3 Technological Innovation, Needs and Technology Assessment

We are wedded to technological innovation. All governments strive after economic growth because growth creates greater revenues without raising rates of taxation and growth generally increases living standards and thus keeps the population happy and gives politicians a chance to be re-elected. The need for innovation as a stimulus to economic growth is caused by stagnation in markets for technical products. If an innovation is successfully introduced, many people are going to buy the new greatly improved technology, irrespective whether they really benefit from the improvement, and the manufacturer can look forward to a new boom in sales.

Because technological innovation can create new markets for the new products, innovation has become one of the most favoured children of all advanced societies. Innovations span a wide spectrum: from minor improvements to technological revolutions. It needs to be emphasised that technological revolutions are generally caused by the creation of a whole technological system, not by a single new artefact. Among technological revolutions we must count the railways, the automobile, the aeroplane, solid state electronics, the computer and worldwide communication networks. Whereas in the past innovations were based on the inventions of single inventors, in the more recent past technological innovation has become a more institutionalized and more anonymous activity. It is now carried out in institutions whose business it is to create innovations, largely based on the research departments of large corporations or on specialist research and design laboratories serving large corporations. The modern state provides support for technological innovation. The support consists of direct and indirect finance for innovative activities, but also takes the form of support for higher education, maintenance of a system of patent protection, state research institutes and, last but not least, military research. The role of military research in the creation of novel civil technologies is influential and highly controversial but I shall not enter this controversy. There is veritable competition between states on the extent of budgetary support for research and development (R&D), but there is also much international cooperation between researchers. Producers of technological products are under constant pressure to innovate and ordinary consumers find themselves under pressure to keep up with the Joneses by buying the latest offerings of industry. The advertising industry and sales promotion tricks keep up the sales pressure and so the wheels turn round creating ever new wants and new sales.

To the economist, every purchase that humans make is a satisfaction of a need. It does make sense, however, to distinguish between needs and wants on the one hand, and, on the other hand, to define some kind of hierarchy of needs. Needs for individuals, in relation to technology and its products, can very roughly be categorized into: 1) needs vital for mere survival; 2) needs arising out of the general standard of expectations within a society; 3) needs for things that make life easier, more pleasant, and more fun. Needs of producers are very different: in simple terms they need everything that increases the efficiency of their production. They may, however, have other considerations in mind, such as decreasing their dependence on labour, conforming to regulations, or trying to be as environmentally friendly as possible. Wants, on the other hand, are goods and services that people buy without needing them. This category applies mostly to luxury goods of every kind. I would suggest that luxury editions of goods or services that satisfy needs of the second and third category should also be classed as wants.

Throughout history technology has been able to satisfy ever more needs and wants, starting from mere survival in the earliest days and reaching the possibility of satisfying every need and want imaginable in modern times. There are virtually no limits to consumption set by technology, but there are very severe limits set by economic capacities and by environmental considerations. Rich

individuals in the advanced countries can fulfil practically every wish and every want. Poor individuals, even in rich countries, often cannot satisfy even the most basic needs and are forced to abstain from everything that has even the slightest whiff of luxury about it.

Whereas in the distant past technology was only barely able to support the vital needs of the population and did not make any profits, in modern times, in the advanced countries, all needs can be satisfied by technology and producers seek ever new outlets for their products. They are no longer content with satisfying needs and modest wants, they now seek to create new wants in order to increase their sales and their profits. If certain products are bought initially just to supply the wants of a few privileged individuals, it occasionally happens that these privileged wants become widespread and turn into needs dictated by social custom. The automobile is a prime example of this process. In the early days of the automobile, at the end of the 19th and the early 20th century, only wealthy enthusiastic individuals bought automobiles. When the automobile became cheaper and lost its aura of adventure, it became a widespread commodity and social adjustments turned it into a need. An ordinary car is now a need and only luxury cars can be categorized as wants. Manufacturers try hard to offer luxury cars on the market because the profit margin on them is much higher than on mass-produced ordinary cars. The fact that luxury cars usually consume much more fuel and tempt drivers to travel too fast is apparently no deterrent for either manufacturer or purchaser.

Modern technology or, to be more precise, modern technologists, accept that they must satisfy as many needs of the population as possible, and yet strive to create as many wants as possible to satisfy their own greed as well as the greed of their customers. The distinction between need and want is a function of time if we accept, as we must, that some needs are socially determined. We distinguish between absolute and relative poverty. A person who cannot satisfy his or her vital needs is absolutely poor; a person who cannot satisfy his or her socially determined needs is relatively poor.

I would like to address one specific problem of Technology Assessment. The Collingridge dilemma (Collingridge 1980) states that in the early days of a new technology its social consequences are difficult to assess whereas when the use of the technology becomes widespread, and its social consequences become apparent, it cannot be controlled because it is entrenched in society and in the economy. The problem I wish to mention is that the assessment of individual components of a technological system can be extremely difficult. In my early days in the Austrian Academy of Sciences I used to receive requests for the assessment of technological innovations that were seeking financial support from the Ministry of Science. The idea was great, but the applications were almost invariably concerned with new electronic circuits or similarly individual components of larger systems and I had to conclude that there were no social consequences of such technologies to be expected. The conclusion is that TA is difficult when carried out too early in the life of a technology and equally difficult if the technology to be assessed is a small component of a larger system. Some components may be crucial to the functioning of the system but most components, though innovative, have little effect on the system and therefore have practically no social effect. Some stand-alone devices, whether electronic or otherwise, though novel and clever, may also be too insignificant to be usefully subjected to TA.

Technology Assessment deals, in the main, with new technologies and thus with the process of technological innovation. There is a vast literature on innovation, dealing with the process of innovation, with the classification of different kinds of innovation and, last but not least, with the process of adoption of new technologies and hence with the effects of innovations. It used to be thought that technological innovation is a linear process, beginning with a scientific discovery, followed by engineering development and, finally, with the production of the new technology. More recent theories of innovation accept that the process is far more complex. Essentially the idea for an innovation is created when a new technological possibility is conceived and is seen as offering marketing possibilities. The attraction of innovation for the innovator is predominantly the possibility of making profits. Other considerations, such as scientific curiosity and ambition do play a role, but the dominant consideration is the hope of making a profit. There is no question of satisfying a

need, the only question the innovator asks is whether a want can be kindled that will lead to sales and profit. The innovator in modern times is very rarely the single inventor, more often than not the innovators are large organizations that are able to finance the lengthy process from idea to prototypes to manufacture to marketing. The innovative idea may or may not come from pure science, but before the next stage of the innovation process is reached, knowledge and experience from many branches of science, engineering and commerce need to be deployed.

Innovations may consist of small improvements or additions to an established technology or they may be the beginning of a radically new technology or technological system. Because innovations are risky and expensive, yet a successful innovation may lead to new sales and thus to economic growth, most governments support a range of policies for the support of technological innovation. The policies range from higher education, patent offices, libraries, financial support for innovators, own research laboratories and so forth. We may speak of an infrastructure in support of innovation. The innovative capacity of a country depends on the smooth functioning of this infrastructure and not merely on direct expenditure for R&D. The innovative capacity of a country depends on the availability of highly trained scientists and engineers, on the existence of innovative and research intensive firms, on the availability of risk capital, and on management structures that support innovative processes and are not content to increase profits from existing technologies by making savings and increasing efficiency. This, by the way, is one reason why firms managed by engineers generally do better than firms managed by accountants.

Virtually all products, not only clothes, are subject to fashion. To follow fashionable trends is vital for the survival of firms and this often involves technological innovations. Thus innovation is necessary not only to increase profits, it is often necessary to ensure that the firm survives in the face of competition.

Innovators are forced to assess, or guess, the degree of acceptance of their innovations. In principle, each new product, unless it is totally new and fulfils new tasks not fulfilled before, needs to be better in some ways than its predecessor product. We often speak of a figure of performance of a product, measuring how its performance compares with similar products. The overall figure of performance is composed of figures for each defining characteristic of the product. It may consist of speed, fuel efficiency, reliability, safety, running costs, ease of operation, and so forth. It is not usually explicitly stated, but buyers know what to expect of a product and have an overall performance in mind for their purchasing decision. Normally we expect a new product that replaces a previous model to have a higher overall figure of performance. In this way technology moves forward in its development in the sense that each successive generation of a technological product either performs better than the older generation or in the sense that the new technology fulfil tasks that the older technology was not able to. We may therefore generally speak of technological progress in the sense that technology improves over time. This forward development of technology is in sharp contrast to social development that tends to move forward and backward in an irregular time-dependent movement. This statement is difficult to justify in any absolute sense because we have no absolute measure of the quality of a society, yet most people will agree that technological progress does exist, whereas social progress is controversial, to say the least.

Questions are often asked about the neutrality of science and technology. Some observers insist that science and technology are far from neutral and indeed serve the interests of either particular social classes or the interests of the ruling elite. I think that we have to distinguish between product technology and production technology and I would agree that production technology is not neutral. Currently the ruling class is interested in reducing their dependence upon labour and wish to avoid the social and political problems associated with managing a huge and potentially difficult to control labour force in a single factory. Thus the current trend of reducing the labour input to production and increasing the capital input must be seen as being in the interest of the ruling capitalist class and ideology, and production technologies that run counter to this trend will not find acceptance.

4 Conclusions

Technology is one of the major factors that determine the course of history and the fate and shape of society. The earliest humans used their wits to survive and made simple tools to help them in their struggle for survival. Gradually the numbers of humans increased and their horizon widened through intercourse with fellow humans. They remained hunters and gatherers who owned virtually nothing and only just survived until, in the Neolithic period, they learned to grow crops and to domesticate some animals. The change from searching for food to producing food was the first fundamental change in human existence. Agriculture enabled humans to become sedentary, to build settlements and create stable social structures. With the rise of farming, the concept of wealth entered into human thinking and striving. I regard the change from a nomadic to a sedentary existence as the first major transition in human society caused by technological change. The rise of the concept of wealth was one result of this transition, and other concepts followed in due course. Sedentary societies formed more or less stable structures with a distribution of wealth and of power. Thus the concept of hierarchies must be regarded as a consequence of sedentary lifestyles, though nomadic societies probably also had some form of leadership. As soon as societies, with their distribution of wealth and power became established, the striving after wealth and power turned into communal striving with the consequent concepts of conquest and war.

It is arguable that the concept of wealth is an important factor in societal development ever since society became sedentary. It follows that the means of production, and thus technology, became a central issue in human affairs. All forms of political and economic organisations that occurred throughout history were related to the state of technology of their time. There can be no doubt that technological developments fundamentally influence the structure of societies and the lives of humans.

The influence of society on technology is similarly obvious. Various members of society and social strata have their needs and requirements that technology is called upon to satisfy. As technology became more powerful, it became a major source of wealth in its own right. Technology now not only satisfies needs, it creates wants and desires in order to satisfy them and make profits in the process. Technology now permeates society to such an extent that virtually all economic and social activities include the use of technology. Indeed information technology, including computers, now acts as an intermediary for most social transactions. Organisations have become anonymous and inscrutable, causing many people great unease and fear. What we might call high culture is now overshadowed by technology.

There can be no question that we need technology, and that many technologies are beneficial beyond dispute. We could not sustain the lives of the vast number of humans living on our planet without the extensive use of technology. Technologies increase our comfort, reduce drudgery, and provide us with a plethora of essential goods and services as well as many inessential ones. On the other hand, there can be no question that we treat the natural environment rather carelessly and that we are profligate in our consumption of natural resources, including energy. We do not take good care of our fauna and flora and allow many species to die out while the human race multiplies. We should be more careful with our treatment of nature and more careful in our treatment of our fellow humans. These exhortations are not new but because of the enormous power of technology and the great pressure of population they have become more urgent.

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