TECHNOLOGY'S CONTRIBUTION TO DEVELOPMENT

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Presidential Address to the AS&TS

The manner in which technology has contributed to the evolution of social structures is traced from the time when man first tamed grasses to found agriculture up to the present when the use of energy to control information represents the ultimate extension of the Industrial Revolution.

From the purely tribal society from which we all originated, the path forks to the religio-nation in which there was adequate water and agricultural surplusses were easy to achieve, and to the city-state in which the absence of water forced the inhabitants to create wealth through trading.

Ultimately the city-state became dominant, and evolved into the proto-nation by the conquest of transport on land. However, the evolution of metals and explosives threatened even this development.

The true nation only evolved after the Industrial Revolution when for the first time man learnt to control energy. Productivity and wealth creation followed, and we are currently searching for the next phase in our development as we learn what benefits we can draw from information processing.

The lessons from the evolution of the West are set against the stage of development of our own country, and it is concluded that, with a combination of leadership and vision, we may move forward as a nation, confident that through technology we may overcome presently perceived problems and evolve for ourselves a society which could prove to be a model for the rest of mankind.

1. INTRODUCTION

Several years ago I spent some time in Lesotho, helping development by boosting tourism through the manufacture of snow for skiing. Some Peace Corps were also there, trying to establish cottage industries. They failed because the society they were endeavouring to help was too poor to be able to accept what they had to offer. It is difficult to support cottage industry when most of your waking hours are spent keeping yourself alive. The cottage products have no ready market, the returns from your labours are anything but immediate, and most of the effort entails *hard* work.

This experience taught me that development is never simple – the whole of the developing society must need, and know that it needs, what the developer has to offer. In poor societies there are no opportunities – it does not matter if you are intelligent, hard-working or ambitious. Opportunity is directly proportional to wealth.

I then asked myself how *our* societies had moved from poverty to wealth? How had *we* acquired the opportunities we enjoy? Why is *our* life-expectancy so much longer than that in the underdeveloped nations? My enquiries into these and a host of similar questions gave me the material for this address.

I start with a pre-industrial society, a tribal society rooted in agriculture, a society with minimal infrastructure, minimal education, minimal cash or credit resources, and minimal life-expectancy.

I then enquire into the role that science and technology play in moving from such a society into the developed society which we represent. The path leads through the evolution of the technology of agriculture and the technology of trade.

Where there was adequate water, there arose what I have chosen to call "religio-nation" development. This was an inward-looking society, with a number of social strata and a relatively developed technology of communication, which enabled the ruling class to control the society. Where water was less adequate, food storage technology became more important and then defence of those stores, which led in turn to the city state, a concentration of skills, and the technology of trade.

The development of the state required all these technologies and more importantly, a technology for rapid communication on land. The first great state to evolve was that of Rome, which finally lacked adequate defence and secure supplies of food. The next states were those of Europe, which rose and fell as trade and the technology of trade developed.

Finally the state of "proto-nation" developed the technological resources necessary to establish a true nation, self-sufficient and self-governing, with the ability to feed an ever growing population under virtually all climatic conditions and able to preserve its borders against virtually all intruders. The trigger to the formation of nations was the Industrial Revolution, when man harnessed energy efficiently for his needs. I believe we are still in the Industrial Revolution as we harness energy for the processing of information.

In all of this, I draw examples from different times and different places. The development of the social structures we know today took place at various rates, and often moved backwards before progressing again. Though there remains some tribalism in all of us, though we have vestiges of the religio-nation and the city-state in our social structures, we are not the end result of a historical process, and my thesis must not, therefore, be seen as history. But it can only end in the present, and therefore I enquire finally into the impact of these findings on the development of our own people from the Third to the First World.

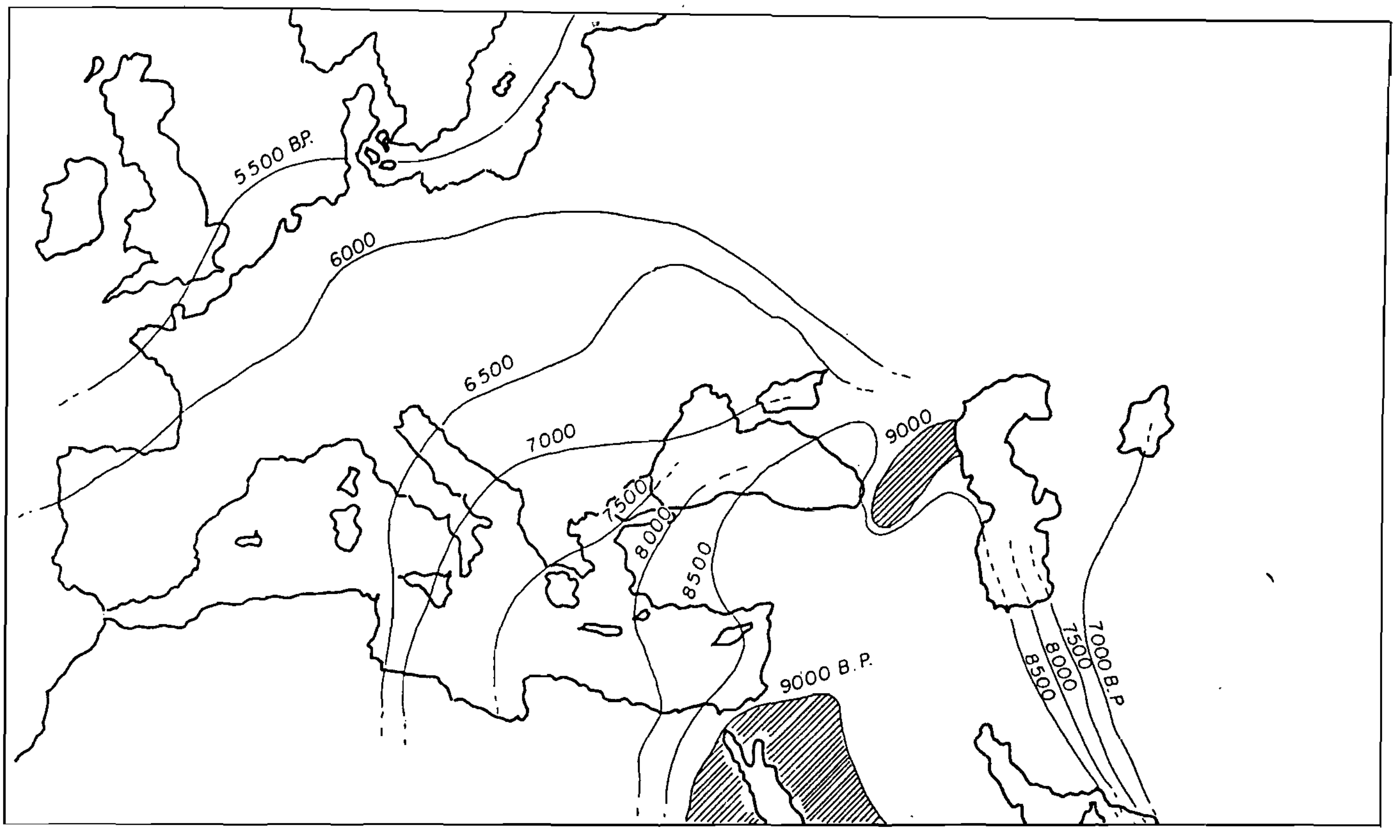

FIGURE 1 THE SPREAD OF AGRICULTURE FROM THE NILE VALLEY AND THE SHORES OF THE CASPIAN OVER THE PAST 9 000 YEARS. THE CONTOURS SHOW THE LIMITS OF THE OLDEST KNOWN EVIDENCE OF FARMING. (BP: BEFORE PRESENT)

2. TRIBAL SOCIETY

I use the phrase Tribal Society in its broadest sense, to mean the society from which we all sprang. It is a society characterised by subsistence farming. Communication is slow, so the society operates only over a restricted geographical area. It has limited storage capacity for food, so there is little incentive to produce any surplus. Land is largely commonage, with small areas granted by a local power to individuals or families. Raiding is common, to enlarge herds or capture limited food reserves, particularly in times of drought or other climatic disturbance. Population balance is ensured by a few communal practices and by war, disease and starvation.

The technology most important to these societies is agriculture. Figure 1 shows the way in which agriculture has spread across Europe and the Middle East since its discovery 9 000 years before present (BP).

Grain, and all the genetic improvement that has gone into making it a staple, is critical. Grain storage technology is rudimentary, even in areas where climatic variability and drought conditions demand sources of food when crops fail.

The technology of animal husbandry is not so essential – probably more thought goes into the breeding of efficient draught animals than into the breeding of good slaughter animals. Animal inputs into clothing such as wool and leather are also not critical. For instance, originally sheep were plucked as they moulted rather than being sheared. A shearable sheep was only bred in about 1000 BC (Ryder, 1987). The Spanish invaders of South America were struck not only by the colours of the clothing available to those 'primitive' people but also by the softness and silkiness of it – the result of using fine wools from animals such as the alpaca and vicuna. Indeed, the sheep only yielded a similarly fine wool once the merino was bred, and the story of its introduction into South Africa (as well as the later introduction of the angora goat) has recently been shown to have laid the foundations of much of our economic development before 1866 (Fleishner and Caccia, 1983).

In tribal societies, the technologies of preparing the soil, irrigation, pest control and finally harvesting the crops are extremely primitive. The animal-drawn plough is widely used; extensive irrigation requires a further development of social organisation; pest control is essentially non-existent; and harvesting relies on human muscle power.

In such a society, communication needs are low, and accordingly there is no communication technology. Verbal skills are high, and memory skills are considerable by modern standards, but writing is not needed. Transport technology is essentially unnecessary – even today, the ox-drawn sledge is used in the foothills of the Drakensberg to move firewood or haul any surplus crops to the store. The wheel came later in social development.

Similarly warfare technology is negligible. Occasionally an unusual technology such as the *iziCwe* of Shaka would emerge and enable a number of tribes to be subjugated to form a proto-nation, but such technologies were rare in the thousands of years of tribal history.

There remain a few true tribes in our modern world (Brain, 1976). However, in the face of technology tribal societies are disappearing. Eskimos have motor boats and insulated wooden houses. The Lapps are using ski-mobiles and thermal underwear.

The reasons for the disappearance are not hard to find. Tribal agriculture is hard physical work. Reducing the physical labour input requires capital, and the investment of capital demands ownership of the land. This simple truth is borne out in the central economies of today – for instance, in Poland I was told that some 60 percent of the food available to the nation comes from the 3 percent of land which remains in private hands.

Tribal society everywhere has been reluctant to give individual title to land. In England during the 18th century, enclosure (the turning of communally controlled land to individual account) took place often in the face of considerable strife. The end result was dramatic. By 1710 there had been only one Act of enclosure. The average mass of oxen delivered to Smithfield market was 170 kg, and that of sheep 17 kg. By 1800 there were over 2 100 enclosure Acts, oxen averaged 365 kg, and sheep nearly 40 kg (Plumb, 1950).

In what is now Germany, in the late 18th century there were over 300 territories and 1 400 knight's 'fees' or fiefdoms. The peasants were truly only free to purchase land as late as 1850, and with the help of the 'Rentenbanken' proceeded to purchase the lands from the lords of their manor. Some 20 percent of these mortgages were still outstanding in 1913, and were written off as a result of the first World War (Borchardt, 1973).

So the acquisition of land, and the development of private capital, has been responsible for much of the disappearance of tribal societies in recent years.

But of course this was not always the case. There were a number of social structures into which tribal society evolved before our present times. Each of these depended to a large measure on the development of new technologies, and each died as a result of the emergence of superior technologies.

3. THE RELIGIO-NATION

One of the first large-scale social structures to emerge was what I have called the "religio-nation". At certain periods all over the world societies developed which were characterised by a widespread allegiance of people towards a central power group, usually sustained by a mystical belief in the god-like nature of the leader and what he or she represented.

The archetype is Egypt. The events leading up to the creation of the Dynasties of Egypt have been the subject of much recent study (Fattovich, 1985). Development was faster in the upper valley of the Nile, where three phases of Naqadah culture have been identified, extending from about 4500-4000 BC (Naqadah I), 4000-3500 BC (II) and 3500-3000 BC (III). The first of these phases was raw tribal in nature. The next two were "characterised by a progressive increase in food production, crafts specialisation and external exchanges" with an associated evolution of a centralised hierarchical structure which led on naturally to the Dynastic period.

What was important was the rapid build-up of agriculture through the adoption of irrigation and the adaptation to the annual flooding of the Nile (Figure 2). Not only did the floods renew the soil so that crop rotation was unnecessary, but also the floods were so reliable that it was hardly necessary to evolve major crop storage technology. Agriculture was therefore extremely productive, and society was able to develop rapidly.

The economy that evolved generated considerable surpluses. Some of these surpluses went into trade, and the presence of the river as a means of physical communication assisted trade. But the volume of trade was of necessity not large because there were few markets. The net result was the development of a social class which, through religious support, was able to commandeer the wealth and create a social fabric which would sustain it through many generations.

There are many other examples of the religio-nation elsewhere in the world and at other times. For instance, in

FIGURE 2 THE NILE FLOOD PLAIN FROM SPACE, SHOWING HOW AGRICULTURE IS CONCENTRATED ALONG THE PLAIN – THE FEEDER RIVERS SUPPORT NO FARMING

1517, Cortes and Cordoba stumbled on the Mayas of Mexico, and were mistaken for the returning god Quetzalcoatl. The Mayan civilization was sustained by efficient agriculture, with a vast network of irrigation and drainage, and this in turn sustained a religion that has fascinated all who have studied it (Hammond, 1986). But the Mayas had no technology of metals other than the precious ones (Figure 3), and had a poor technology for physical communication (Collis, 1963).

Similarly, in 1532 when Pizarro marched into the interior of Peru, he found "The soil, though rarely watered by the rains of heaven, was naturally rich, and . . . the industry of the inhabitants had turned the streams to the best account, and canals and aqueducts were seen crossing the low lands in all directions spreading over the country like a vast network, diffusing fertility and beauty around them." (Prescott, 1901). Again, this had led to surpluses sufficient to sustain the Inca kings in wealth, without the benefit of trade. They had all the technology of hydraulic engineering. They had road technology without the benefit of the wheel. Internal communications via pieces of knotted string were at least as efficient as writing. Yet the building technology was of the crudest – it has recently been shown that those extraordinary erections of Cuzco, Machu Picchu and other remnants of Inca civilization were created by bashing big stones with smaller ones (Protzen, 1986).

The same pattern emerges around the world – China, India, South East Asia all provide similar examples (Fairservis, 1983; Higham, 1984). Adequate water leads to adequate agriculture and the emergence of a leisured class with little interest in conquest or trade except to provide what can only be described as luxury goods.

The religio-nation was brought to its end by the rise of technology. It had no counter to the aggressive expansionism of the agglomeration of city-states which were growing into the proto-nations that have become the nations we know today. Perhaps the last religio-nation to fall was dynastic China when, following the Boxer Rebellion of 1900, the Empress Tz'u-hsi finally succumbed (Warner, 1972). In this, it was no different from the fall of tribal societies

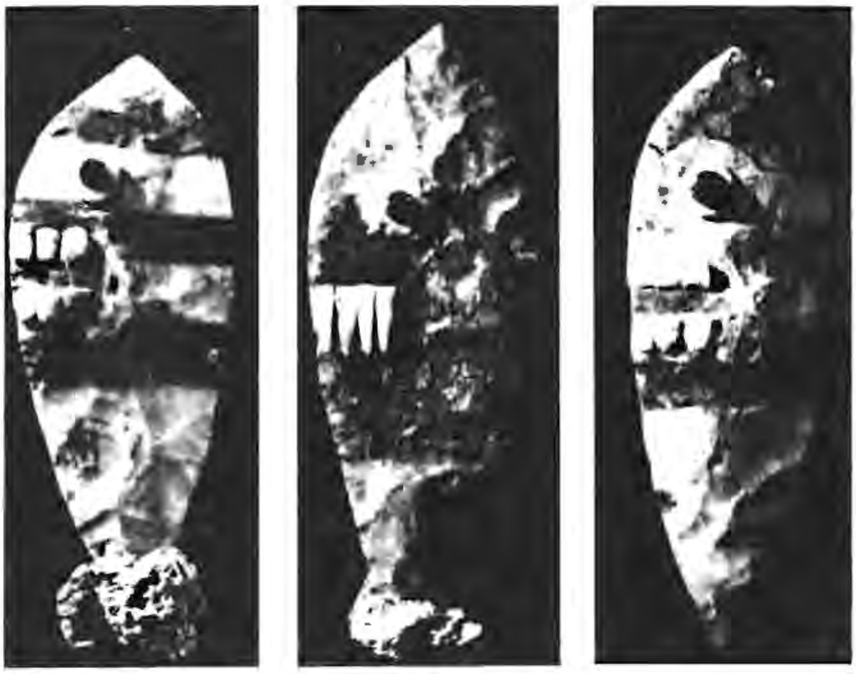

FIGURE 3 CEREMONIAL MAYAN KNIVES IN STONE FROM ABOUT 1 500AD – "THE MAYAS HAD NO TECHNOLOGY OF METALS"

throughout Africa when faced by European colonialism – the technology of the conqueror was dominant.

How did the dominant technology evolve? It is to this question that we must now turn.

4. THE CITY-STATE

The city state was characterised by a small number of people living within city walls, usually surrounded by an agrarian population wich could be housed within the city should the need arise. One of the earliest examples is that of Jericho, 7000 BC, which was a walled village about 5 ha in extent. However, it was a transitionary phase, still reliant upon the technologies which had sustained the tribal societies, and the first true city-state with novel technologies only emerged some 500 years later.

This was at Çatalhüyük, some 100 km north of the Mediterranean coast in the foothills of the Taurus in Asia Minor. Here some of the first numeric records appear, and a technology of stone polishing was developed. Obsidian mirrors were produced in quantity, and exported along a trade route to the south. The city also evolved some of the earliest known weaving, using a warp-weighted loom. Pottery, which had been known for millenia already, was widely made – the importance here was that the form of pyrotechnology needed for firing pottery could readily be adapted to the extraction of metals, and soon there was also a thriving trade in copper and lead (Grant, 1969).

Catalhüyük established a social pattern that was to persist for 8 500 years. In Western Europe the city-state essentially disappeared with the unification of both Germany and Italy in the 1850-1870 period, though anachronisms such as Monaco and San Marino persist to this day.

The city-state relied heavily upon defence for its well-being. The city itself was usually built in a defensible position, and invariably fortified. It required defence because, lacking adequate agricultural surpluses, it had to protect its reserves of food.

The city-state derived its strength from technology (Figure 4). Usually there were a few specific technologies found in any one city, which provided the basis for trade with others, thus creating a surplus of wealth which enabled the residents of the city to pay for their food supplies from nearby farms.

These specific technologies were many and varied, and the cities which depended on them are recorded in our language – Venetian glass, Brussels lace, Manchester goods, Lyons silk, Damask

FIGURE 4 THE TECHNOLOGY OF A CITY-STATE – VENETIAN GLASS OF ABOUT 1500AD

– the list is endless. One of the more interesting I stumbled across was that of Byblos, which around 2500 BC was an important port on the coast of what is now Lebanon. It gave its name to the papyrus which is handled for the Egyptians – and thus has come down to us as the Bible, bibliography and, in Afrikaans, *biblioteek*.

The city-state depended on the skilled craftsmen who, in Europe, formed the guilds. The skilled crafts were nothing if not protectionist in nature. They held the monopoly on every trade that existed, and their secrets were so closely guarded that modern science often has to use its utmost analytical skills to uncover them. The art of the blacksmith is typical – as long ago as 400 BC smiths were hard-facing adzes and other tools with an austenitic layer for wear over a ferritic core for toughness (Maddin et al., 1977).

This meant that within the city of the city-state there were the rulers, the traders and the craftsmen, with a few others providing services such as the distribution of food or the removal of refuse. Outside the walls were the peasant farmers, who were usually only allowed into the city on market days. Studies of Arab cities have shown the same pattern extending over hundreds of years (Fragner, 1985; Dostal, 1985; Gingrich, 1985).

The emergence of a specific technology usually required the development of the technology of trade. Trade exists in tribal society, but it takes place at a pace which makes it, to our eyes, almost unrecognisable. Time was thus a technology that had to be developed in support of trade. The calendar which was adequate for agriculture was useless for interest calculation. The story of the evolution of accurate time-keeping in the Middle-East has been told many times, but it is salutary to realise that the calendar we use today, the Gregorian calendar, is 405 years old. By 1582 the old Julian calendar was nearly 11 days out (Moyer, 1982), and Pope Gregory created a committee which provided us with an answer that will last for nearly 2 000 years before it needs revision.

There was also a need to record transactions, what goods had been sent so that the receiver could check the accuracy of the delivery. About 3000 BC there arose a system of sealing counters inside a clay envelope or "bulla", and recording the number of counters on the outside of the bulla – an early form of double entry (Schmandt-Besserat, 1987). From numbers it was a short step to measurement, and shortly after 3000 BC the first school text appears. Problems with squares appear, and the conversion of length into area. The number base was sexagesimal, but the concept of zero was lacking (Friberg, 1984).

The earliest technology of numeric communication was inscription in clay, and some of the first writing, that of the Harappan society of the Indus valley, was on this material also (Fairservis, 1983). Soon, however, there emerged the papyrus of Egypt – "Set your heart on being a scribe, for a book is of greater value than a house, than the tombs in the west. It is more beautiful than a castle, or than a sculptured slab in a temple" said an Egyptian of the time (Grant, 1969).

Trade also required the technology of money. The Lydians of Asia Minor were the first to cut designs into a metal surface using intaglio dies, and thus created the first true coinage. Initially it was made from natural electrum, an alloy of silver and gold, but both the colour and content of precious metals varied in the alloy, which led the Lydians to establish a refinery for gold and silver for coinage (Grant, 1969).

Physical communication also progressed. The horse arrived with the Hittites about 2000 BC, and at about the same time iron became plentiful. This led to wheeled transport, although at first the wheel was military rather than civilian. By the time of Solomon, the chariot was widespread and the fortress at Megiddo had 450 horse-boxes (Grant, 1969).

Transport by water was, if anything, more important (Figure 5). Many of the city-states were built close to the sea, but not on it, so as to avoid risk of surprise attack. Athens, for instance, was served by the port of Piraeus, and Troy kept a benign but remote eye on the Dardanelles. Ship building was a major enterprise, with the timber of Lebanon and Ionia being decimated to provide material. The Egyptians had too little timber, and their vessels were only good for transport on the Nile. As a result, their trade faltered, and Phoenicians from the Lebanon and Greeks from Ionia won the markets of the Mediterranean lands.

FIGURE 5 A PHOENICIAN SHIP, KEY TO TRADING SUCCESS

Not surprisingly, competition led to clashes, and clashes led to a technology of sea warfare. Two and three rows of oars, with each oar rowed by as many as four men, drove battering rams weighing up to 20 tons (Foley and Soedel, 1981). Each ship carried a number of marines, some of whom had boarding duties and some of whom fired catapults which were capable of throwing 80 kg stones more than 200 m (Foley and Soedel, 1981). Cruising speeds of over 16 km/h were achieved, with peak battle speeds of over 21 km/h.

Ultimately each city-state had too small an agricultural base to be able to support itself in the face of a population explosion. For instance, the cities of Greece were contained between fingers of mountains which restricted the land available to each. The cities of the Levant were backed by mountains behind which lay a desert. They therefore grew by colonisation, the establishment of remote trading centres. The pattern of expansion driven by population growth was to be repeated throughout history.

However the city-states lost control over their colonies, largely because of the slowness of communication and the growing lack of allegiance of the colonists to their city of origin. Too weak to stand alone, time and again they fell prey to marauding hordes. Nevertheless, as time passed defence and other technologies were brought to their aid, and many city-states had an extended life.

A typical example of such an advance was the provision of water. Athens at its peak after 500 BC numbered about 150 000 free men and 70 000 slaves. Rainfall of about 400 mm was sufficient for wheat on the better soil and barley on the poorer. Early Athens relied upon water drawn from an underground spring outside the city's walls. This sufficed until about 530 BC when the 'tyrant' Pisistratus built an aqueduct to give Athens a "much-needed water supply" (Kitto, 1951). It is not surprising that less than 100 years later, when the populace packed into the city because of an attack by the Spartans, there was an outbreak of a plague which sounded suspiciously like typhoid, and which killed Pericles.

From ancient Greece until modern Europe the city state survived as a social structure. Agriculture, trade, water and communications were the key to their success; the city was guarded by walls of masonry. The arrival of gunpowder destroyed the comfort of masonry, however, and changed the technology of defence. Even so, another technology was necessary before the true effect of gunpowder was felt. The Chinese, inventors of gunpowder, had relied upon casting to make their weapons. In Europe, the rise of the iron industry and the technology of iron fabrication allowed far more powerful guns to be made, guns which were truly effective against massive walls.

Without defence, the city-state was doomed, and new social structures were forced on the world. The thrust for nationhood had arrived, and there followed a period of turmoil which probably ended in Europe about 43 years ago, when the boundaries of nations became fixed by nuclear forces so strong that he would be brave indeed who would attempt to change them.

5. THE GROWTH OF THE PROTO-NATION

Of course, there were nation-type structures before this. The archetype is Rome, which took all prior technologies and advanced them to such a degree that the Roman state survived attacks that would have brought earlier social structures down far sooner.

Consider, for instance, the technology of water. Even before the founding of Rome, the nearby town of Veii conserved water in cisterns and controlled the flow through its moats by lengthy tunnels. By the time the Roman population had reached half a million, the city had a huge sewer, the Cloaca Maxima, which still exists and is in use, and had a network of canals and aqueducts. All this in spite of the fact that, unlike Athens, Rome was build on a river.

The provision of water on this scale demanded advances. There were the great aqueducts, of a size that made them marvels of the medieval world. They were made possible partly by advances in architecture, but partly also by the discovery of concrete. The use of lime mortars was known by 2000 BC, but the Romans discovered that a volcanic ash known as *pozzolana* reacted with lime in a kiln to yield a concrete that was not bettered until the invention of Portland cement (Grant, 1969). This invention permitted not only the waterproofing of canals and aqueducts, but the construction of harbours and of public buildings on a scale the Greeks could not have foreseen.

Rome's water system was largely complete by AD 50 (Figure 6). By that time there were at least nine major aqueducts bringing water from as far away as Subiaco; the Subiaco aqueduct was 90 km long. Hills were tunneled where they could not be avoided, valleys up to 50 m deep were crossed by bridges, and valleys between 50 and 150 m deep were traversed by siphons, marvels of hydraulic engineering (Smith, 1978; Hodge, 1985).

The Romans developed the use of water further – they evolved water wheels to a high level, and dotted Italy with mills for grinding corn. They also assisted agriculture in North Africa by extension of *wadi* technology, the damming of normally dry valleys to capture silt brought down in times of flood, and the use of the plain so created for growing crops. It is surprising to reflect how dependent on Carthage and Egypt Rome became for its food, and indeed by 400 AD the army was so tied down in North Africa that it could not be released to counter Goth attacks in Europe (Grant, 1976) which contributed to the fall of Rome.

No technology was more important in the growth of Rome into a proto-nation than the technology of physical communication on land. The Roman roads are legendary, and they set apart Roman society from all others that had gone before. Rapid communication, on foot or by wheeled vehicle, enabled Rome to control an empire that ringed the whole Mediterranean and crossed Gaul into Britain. Its rulers could and did travel the length and breadth of the empire, and established a presence in places as far flung as Trier in the Moselle valley of Germany, Sirmium on the Save in Yugoslavia and Sofia in Bulgaria, to name a few of the lesser-known centres (Grant, 1976). These were towns of no mean substance – at Trier, for instance, the Porta Nigra survives in a massive four-storey building to this day, and the hot-water supply to the Emperor's bath covers at least a hectare.

The Roman state was the epitome of the proto-nation, and it grew into an empire, fell, and was not replaced as a social structure in the West for 1 000 years. By the Renaissance, many of the old city-states had recovered, and grew into proto-nations themselves. As the city-states revived, they used the technologies of the Roman Empire.

Until late in the 18th century, the economy of Western Europe was largely based on agriculture, with typically less than twenty percent of the population urbanised, and with three quarters of those who were so urbanised living in 'towns' of less than 20 000. Elsewhere in the world society was perhaps less benign – feudalism was the lot of the fortunate, and slavery the fate of the majority. A study of parish records from 16th Century Britain showed that the gentry lived a full three score years, and had three to four children, all of whom survived childhood, while the yeomen died young (barely 10 percent reached forty), the peasant women died before the men, and infant mortality was as high as 50 percent in the lower classes (Cowgill, 1970).

What was happening was that the foundations for development were being laid. Trade was becoming more sophisticated, and both banking and insurance were growing in importance. Communications were improving, and the rise in canal transport meant that the interior was linked to the ports far more efficiently than previously. Fuel could be shipped over long distances, so the iron industry was able to expand. This did not happen at the same pace everywhere in Europe, but movements were in the air from the 15th century onwards.

For instance, Venice grew by trading. This demanded a technology of transport, a technology of accounting and a technology of defence – the latter made easier by Venice's strategic siting. Spain and Portugal (as they now are) grew by conquest in the West and East

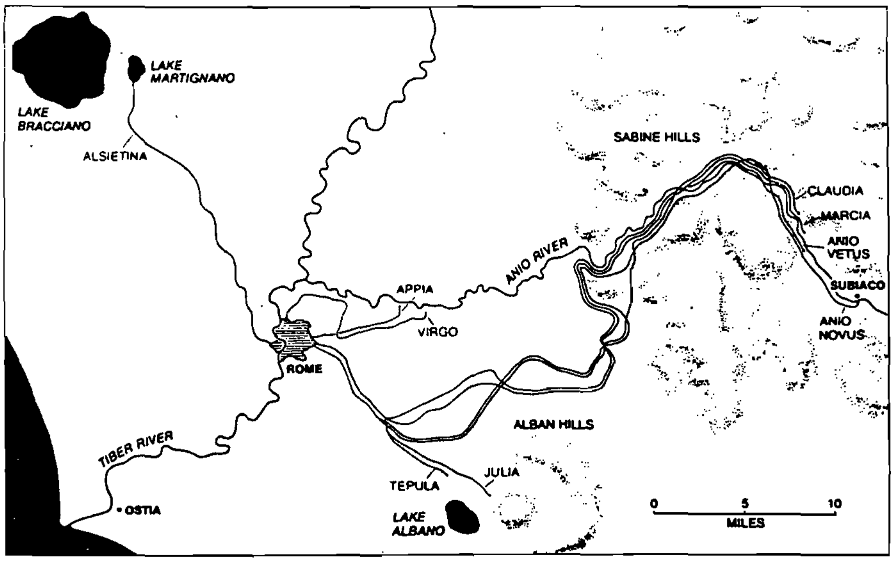

FIGURE 6 IMPERIAL ROME'S WATER SUPPLY IN ABOUT 50AD

respectively, and the acquisition of all the wealth the new territories had to offer. Then Britain and Holland challenged their dominance in sea transport technology, and were able to grow by conquest in turn.

Whatever the reason for economic growth, within each proto-nation there existed growing economic dependence of various areas on each other. Trade, and the communication routes it involved, expanded. Undoubtedly population growth had an impact, but whether this was a prime cause of economic growth, or whether economic growth led to population growth, is not certain.

The net result was an expansion of opportunities in the cities, a growth of the cities and a growth in the infrastructure needed to sustain them. This infrastructure covered all manner of technologies from the collection and distribution of food, fuel and water, to the methods for the defence not just of the cities but of the whole supply system which sustained them – i.e. the defence of the nation as a whole.

But the technologies they employed were no different in essence from those which had sustained the Romans. Something then changed – which leads us to the next stage in our tale.

6. THE INDUSTRIAL REVOLUTION

"Owing to the intensive use of machinery and to the division of labour, work . . . has lost all individual character and, consequently, all charm for the workman . . . The modern labourer, instead of rising with the progress of industry, sinks deeper and deeper below the conditions of the existence of his own class. He becomes a pauper . . . " (Marx and Engels, 1848). Read with our present knowledge of the development of society, they are words which are clearly wrong – the generation and use of power has freed and enriched the workman to a far greater extent than Marx or Engels could possibly have foreseen.

The first technology to evolve and give a hint of what was to come was that of machinery. It was only a hint – the machinery invented for spinning and weaving cotton still used the technology of an earlier generation. Consider, for instance, Arkwright's advertisement – "Wanted immediately, two Journeymen Clock-Makers, or others that understand Tooth and Pinion well: Also a Smith that can forge and file. Likewise two Wood Turners accustomed to wheel making, spoke turning etc" (Burton, 1984). These were the technologies available to build the new spinning jennies and water frames, the source of British wealth in the eighteenth and early nineteenth centuries.

These technologies differed from those of earlier generations only in that the rise of chemistry and physics permitted advances in the technologies of materials, which in turn enabled men to build stronger, more reliable pieces of machinery. In France, mechanisms had been evolved to a high degree for the amusement of the upper classes. In Britain, the home of the industrial revolution, those mechanisms were put to more productive effect.

But the real advance was the development of sources of energy other than the wind, water or the muscle power of some of the larger mammals. This first showed itself in the mines of Cornwall, where development below the sea had made it imperative to find more efficient means than animal power of dewatering the workings. Suddenly there was a motive power that did not dry up; that did not require feeding when it was not working; and that was, to all intents and purposes, limitless.

The effect of this was that man was able to produce more of his needs for himself than ever before in history. Wealth could be created on a scale none had imagined. The whole of mankind gained freedom of expression, freedom of movement, freedom of communication, and freedom to live on a scale that previously only kings had been able to enjoy.

Economists are hard put to understand the importance of energy. "Whatever the British advance was due to, it was not scientific and technological superiority . . . few intellectual refinements were needed to make the Industrial Revolution . . . " wrote a recent economic historian (Hobsbawm, 1962). The take-off of the economy had to be ascribed to " . . . a historical situation, in which economic growth emerges from the criss-crossing decisions of countless private entrepreneurs and investors." Yet that historian admitted " . . . For the first time in human history, the shackles were taken off the productive power of human societies . . . By any reckoning this was the most important event in world history, at any rate since the invention of agriculture and cities."

The first widely applied engine was that of Newcomen (1712), but it suffered from a fatal thermodynamic flaw, with the result that it was relatively costly to operate. Moreover, it was very slow acting and unbalanced, so while it was ade-

FIGURE 7 EARLY POWER-DRIVEN LOOMS

quate for the task of raising water from mines where other sources of energy were absent, it found little use as a prime driver elsewhere. Watt's adaptation (1769) improved the efficiency of the engine nearly five-fold, and it was soon modified to provide rotary motion at reasonable speeds. The engine finally came of age in 1800 with Trevithick's double acting machine, and from then on mankind was freed of the horse, the cow, the wind and water as the prime sources of energy.

The impact of energy on productivity was revolutionary. For instance, in spite of all the technical advances in spinning and weaving machinery, the cotton business accounted for less than 0,5 percent of Britain's gross national product in the 1780s. By the first decade of the nineteenth century, cotton was more than 5 percent of the GNP, more than wool, the prior century's staple of British industry (Deane, 1973) (Figure 7).

Similarly, energy was used to blow air in iron-making (first done by John Wilkinson of 'Wilkinson sword' fame in 1776, the year of the American Revolution) and suddenly Abraham Darby's use of coke instead of charcoal became not another madcap idea, but the whole basis of the British steel industry. The industry quadrupled its output in less than twenty years, and so led to the downfall of Napoleon.

Cheap iron led to an explosion in producer and capital goods. Suddenly there were economies of scale which no entrepreneur could afford to overlook. The sheer flexibility of remote energy generation enabled production to be sited at the optimum place for the distribution of the products, rather than being placed next to nature's bounty where distribution might (and often did) present problems.

A similar pattern was followed throughout Europe. In France, the arrival of energy was delayed by the Revolution and Napoleonic wars. "Modern" engines were only introduced after 1815, and the 600 installed by 1830 grew to 12 000 by 1850 (Fohlen, 1973). Between 1820 and 1860 coal consumption went up more than eight-fold. Power looms were introduced in the 1820s and by the 1840s there were over 20 000 in use in Alsace alone, although the dominance of power over hand-weaving occurred only in the 1870s in Normandy and in the 1880s around Lyons. Germany's industrial revolution was delayed almost until the 1850s. As late as 1831, 74 percent of all Prussian linen was hand-woven by men who had no other occupation (Borchardt, 1973). By 1840 Saxony, the most industrialised German state, had started to use steam power and had less than 50 engines with a total installed power of about 700 kW.

The fragmentation of what is now Germany restrained technical and economic development. In the 1840s the tiny states which made up Germany first established a customs union, the *Zollverein*, but full political unification had to wait until the 1880s. When the political problems had finally been resolved, Germany took off with a vengeance.

Within thirty years Germany moved from being a collection of tribal homelands into a major player on the map of Europe. The pace of urbanisation was hectic. The number living in cities and contributing to industry and trade quadrupled between 1880 and 1910. Industry's contribution to the net domestic product went from less than 30 to over 40 percent, communication's contribution went from 2 to nearly 7 percent, while domestic service fell from 6 to 2 percent. Railways grew from 3 000 to nearly 10 000 km.

To the south and east of Germany, the revolution was delayed by the conservatism of the Habsburg monarchy. Peasant emancipation took place following the civil disturbances of 1848, and only after then did industry start to take off, doubling in output over the next fifteen years (Gross, 1973). Weaving was mainly by hand until the 1850s, although in 1841 in the Vorarlberg one-tenth of the looms were powered. Per capita coal consumption was then one-twentieth of that in Belgium, and iron production was half that of France.

Italy came even later (Cafagna, 1973). Its textile industry was mainly based on silk, so the means of mechanisation which had been so effective for cotton and wool took time to adapt. In addition, political unification occurred after 1860. Each of the tiny states which were to come together to make the nation Italy were extremely protectionist in their trade relationships, and innovation was accordingly stifled. Even fibre processing took until 1890 to be fully mechanised, while iron production largely depended upon imported material until the same decade.

Belgium and the Netherlands presented an interesting contrast (Dhondt and Bruwier, 1973). The exploitation of the coal seams running through the hills in the south of Belgium resulted in the early adoption of the Newcomen engine, and by the early 1830s the use of steam power was widespread, with over 1 000 machines in use. Cotton and wool spinning and weaving flourished in the 1830s, while iron and steel production soared in the same decade. However, Holland was slow to adopt steam – only two engines were in use by 1800 and 72 by 1837. Industrial growth followed the rise of the steamship, when the Dutch marine interests started to repair and later build boats. This remained on quite a small scale, and as late as 1850 the two major shipyards together employed only some 1 450 workers. The use of power in fabric manufacture was similarly delayed until the late 1840s, and "the results were remarkable – pauperism disappeared from Twente almost overnight."

Energy was the trigger to this revolution. There followed socio-economic changes and a shift in the entire structure of industry which has continued to this day. The magnitude of these changes is difficult for us to appreciate, even though they were so recent. For instance, in 1870 the life expectancy of a German male at birth was thirty-six – by 1913 it was forty-five. Not surprisingly, the industrial revolution was accompanied by a population explosion almost everywhere.

The demographic effect was not necessarily a depopulation of the farming sector. What happened was that the surplus labour tended to move to the developing towns. That surplus was not as great as is sometimes thought because the emancipation of the peasants had the unexpected effect of requiring more labour on farms, not less (because fences and hedges had to be created and maintained, and also because newly enclosed lands often required drainage systems to be dug).

Nevertheless there was very considerable stress on towns everywhere. The infrastructure they possessed was quite incapable of dealing with the influx of people seeking work in the new factories. In Britain, for instance, the manpower in agriculture grew from 1,7 million in 1800 to 1,8 million in 1870, while that in industry grew from 1,4 million to

5,3 million over the same period (Beaud, 1984). In France, the slower arrival of the industrial revolution, and the release of the lands of both church and nobility at the time of the Revolution meant that agricultural manpower grew faster than in Britain (from 5,5 million in 1790 to 7,2 million in 1870) and industry grew more slowly (from 1,6 million to 3,8 million over this period).

Most towns, and certainly those that had vestiges of walls from their city-state origins, did their best to control the influx. Others such as London suffered. " 'Let me see that shop,' I said . . . There were seven rooms in this abomination called a house . . . The seventh room we entered. It was the den in which five men 'sweated'. It was seven feet wide by eight feet long and the table took up the major portion of the space . . . In the adjoining room lived a woman and six children." (London, 1903). This was Britain's capital city in 1902. One million people lived comfortably in the West End, and eight million lived in abject poverty in the East End. Of these latter, some 900 000 were housed in condemned buildings, and 125 000 were inmates of workhouses. Disease was rife, crime was prevalent, and there were all the other signs of social stress. What miracles have been wrought in the past eighty-five years!

Overcrowding was worsened by the sudden arrival of mobility on a scale that captured the world's imagination. From the earliest commercial railway line (Stockton to Darlington, 1825) it was five years before there was over 50 km of line in the whole world. By 1840 there was over 7 000 km and by 1850 over 40 000 km (Figure 8).

Everywhere trade was stimulated by this new-found means of transport. There were the railway booms, followed inevitably by slumps, and the capital poured into the extension of the lines offered a meagre return – in Britain in the 1850s, a paltry 3,7 percent (Hobsbawn, 1962). Nevertheless, the iron industry surged, the coal industry was carried along, and the civil works of tunneling, embanking and cutting em-

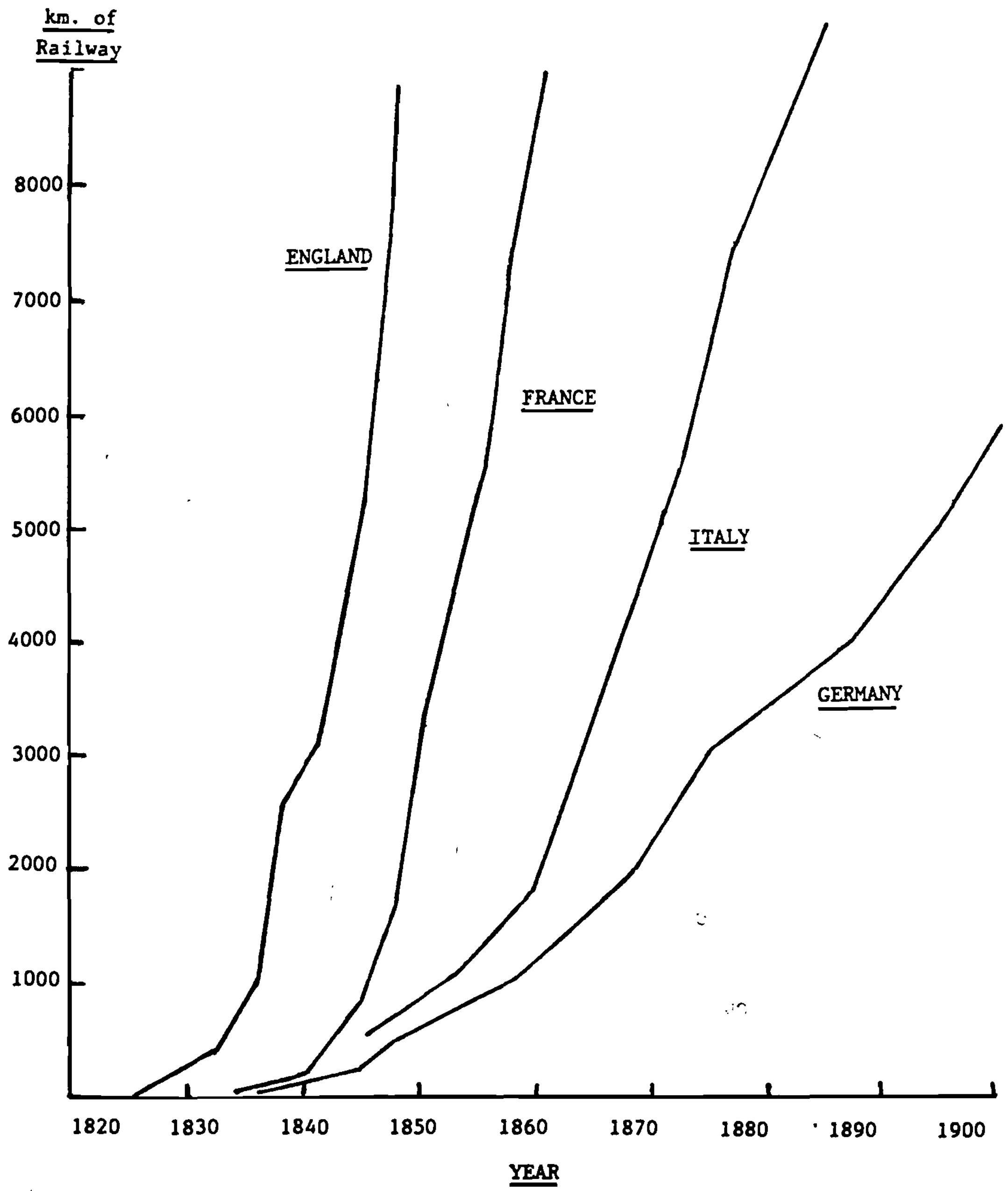

FIGURE 8 THE GROWTH OF THE RAILROAD

ployed thousands on a scale seen before only at the building of the pyramids (Figure 9).

The ability to move agricultural produce rapidly and cheaply to the cities meant that the city was finally isolated from the effects of the weather – crop failure in one part of the country could be made good by produce from elsewhere. The markets of the great cities grew in size, diets improved, and with them life expectancies.

In general, during the period of railway expansion, there was greater growth in capital goods than in consumer goods, but consumer goods grew nevertheless, and in due course became as important. Inventiveness played its part, and the development and control of, first, gas as a source of energy and then electricity brought undreamt-of benefits to mankind. Communication was enhanced by the speed of the electron, and from the telegraph we have moved to the fax with morse-code a distant aberration.

The harnessing of energy has changed the world in a way which makes all previous history of society seem almost trite. We are still in the harness mode – we have barely learnt to control the atom, and we are nowhere near the end result of turning energy loose on information. The latest machine to cross my consciousness can be driven at 2,5 gigaflops – last year's supercomputer was up to only 400 megaflops (Hillis, 1987). Probably the most important discovery of 1987 is superconduction at way above 40°K – but perhaps we are all too close to such events to judge. Gödel proved that the machine, in its broadest sense, could not understand itself, and we are such machines.

The fact that we are still learning to use energy means that we are still in the Industrial Revolution. Nevertheless one effect of the Industrial Revolution can be taken as being essentially complete, and that is the evolution from protonation into nation. The face of the globe is now largely covered by social structures which, because they have integrated agriculture, water, communication and trade into a coherent whole to the benefit of their peoples, are unlikely to change for the foreseeable future. The nation has arrived as a social structure, and seems likely to stay for a while to come.

FIGURE 9 RAILWAY CONSTRUCTION

We have hastened from the railway to the ultra-computer, from the drift into the cities of Europe to the explosion of the lands of the Orient into industrialisation. Now we must turn to what these reflections mean to us, caught as we are between the tribal and the computer worlds.

7. DEVELOPMENT IN THE WORLD OF ENERGY

First agriculture, then water, then trade and transport, and finally power.

Imagine yourself, if you can, in a tribal society alongside the wealth of today's South Africa. You have a form of right to land – you have negotiated with your local chief, and if you are lucky he recognises your brithright without asking too much in return. You have a family, and they can help you with the chores of agriculture. You have the barest necessities of life – perhaps a cow, a few chickens, a few utensils, a little seed, and lots of friends, without which no man can exist.

With effort you can make that land productive. You can plough and weed, you can fertilize and water, and when day is done you will be glad of a bowl of porridge and a hard bed.

Or you can go the few kilometres to the nearest town, where you may find yourself work. You will leave behind your family, and they will not farm very well, but they will maintain your right to land, and rights will be established for your children. In the town, your job may pay but a pittance, but you have access to all the experiences of the West – the radio, the doctor, the taxi, the hamburger and money.

Those are the choices you face – which do you choose? There is no choice, the West has won (Figure 10). The children

FIGURE 10 "IN THE TOWN, YOU HAVE ACCESS TO ALL THE EXPERIENCES OF THE WEST"

will struggle, the wife will complain, but first the man, and then the family, will move as close to the obviously successful First World as they can. With time, they will establish themselves, their diet will improve, their demands on their bodies will be less, they will be part of a public health system, and they will live longer. They will gain in education, create for themselves opportunities for contributing to the generation of wealth, and will come to rely upon lifetime savings rather than a plethora of children to care for them in their old age. The birthrate will fall, and the population will stabilise.

Of course, it can be argued that this is too naive a view of urbanisation. Undoubtedly acquisition of tribal land by Europeans, and the turning of the original occupants into tenant farmers, played a role in forcing early rural residents off the land (Keegan, 1986). The need to earn cash to pay taxes may also have played a role (De Kiewit, 1941). Nevertheless, the major rush to the cities is occurring now, and these earlier phenomena can now, to all intents and purposes, be disregarded.

The first stages in the present-day urbanisation process are well documented in a recent study in Swaziland (Low, 1986). The migratory workers who are the subject of this study take all possible steps to minimise their labour inputs to the farm in order to maximise their work opportunities. Hybrid maize has been widely adopted, and has *not* yielded the anticipated increase in harvests, because the labour inputs have been reduced, not increased. By planting hybrid maize, the worker gains a subsistence reserve with less work, rather than producing excess maize for the market.

Attempts to halt this process, or even to control its pace, are likely to be frustrated. If you only have to move a few hundred kilometres to double your life, then you will move, regardless of the ties that keep you at your place of brith, and regardless of obstacles that well-meaning people may put in your way.

Why would obstacles be placed? There are a number of perceived problems – housing and social infrastructure in the cities are too limited to accept the flood of people, for instance, and slums will be the inevitable result (Figure 11). This is true, but is it necessarily a problem? Every society which has been through this phase of urbanisation has been faced by slums, because at the height of the flood to the cities the rate of influx has always been faster than the rate at which the infrastructure can be extended. Then the flood has ebbed, the infrastructure has caught up, and a new equilibrium is established.

FIGURE 11 "EVERY SOCIETY HAS BEEN FACED BY SLUMS"

It has to be remembered that, ghastly as a slum may appear, for those living there it is still preferable to the life they have left, or why else would they have left it? Our technology has created for us a social structure which is the best available, and there is sufficient spin-off from it for what we might perceive as crumbs to be seen as riches by others.

Every society has taken some steps to try to stem the flood, except perhaps the United States and Australia. Elsewhere all manner of policies have been followed – in much of Western Europe, for instance, there was a strong feudalism until quite recently, and the peasantry was forced to remain on the estates.

In France, this certainly contributed to the Revolution, with the additional factor that the years of the 1780s had seen disastrous crops, and both starvation, inflation and crippling taxation were the result. Similar factors were involved in the Russian revolution also.

Where the policies have not led to revolution, they have been markedly ineffective – slums came just the same. P'yŏngyang, capital of North Korea, is presently successful in controlling its growth, with predictable rural problems. Ho Chi Min City (previously Saigon) was successfully reduced from 4,5 to 3 million over about six years, but the levels of coercion employed would be seen as unacceptable by many societies (Vining, 1985).

Of course, technology has the last word about the problem – in many First World countries today, the core regions are being depopulated and the rural areas repopulated because modern telecommunications permit people to live in rural areas with no loss of opportunity (Vining, 1982). Core growth is a phase in social development, and because social development is driven by technology as much as by anything, the efforts of the social planners to slow the growth of cities or to create artificially alternative development areas are bound to be frustrated.

Urbanisation is not the only question of local importance which this study has addressed. One of the more interesting observations was how lack of unification prevented development in Germany, Austria or Italy for so long. Based on this experience, there would seem to be cogent reasons for *not* continuing to pursue our present policies of fragmentation, but rather to return with all due speed to implementing the spirit of our national motto – unity *is* strength.

A further theme which emerged was how the understandable desire of some to maintain tribal agricultural and land tenure practices might be counterproductive. Everywhere, once land was given value, once communal ownership died, and once men had a direct, personal interest in their real estate, agriculture became productive. For us this means that our tribal authorities should begin to consider the prospect of enclosure if they are to generate the food needed to feed an ever-expanding population. This will mean a social revolution as deep as any we face, but if we recognise that it must be faced, then we will be in a better position to minimize the social disruption that may result.

A theme which was covert rather than openly expressed in how attempts to create labour-intensive work are actually a waste of time. We are beginning to emerge from the fallacy that industry can be divided into "labour intensive" and "capital intensive" groups. We have before us the example of one of the most "capital intensive" industries in the World, Sasol. It is clear that Sasol not only has comparatively few jobs within its fence, but also has such a range of jobs *outside* that the capital investment per job created is actually quite small. There are all the service jobs – the butcher, the baker and the Sasol candle maker. There are the people maintaining the equipment, there are those packaging the products, and there are those who drive a fleet of vans on delivery. These are the *direct* jobs, and you only have to go as far as that to realise that this "capital intensive" factory is not quite all that it seems.

The phrase "capital intensive" is a gross oversimplification. The nations of the First World are more sophisticated than that – they recognise most "labour intensive" work for what is – unproductive. Unproductive work is uneconomic; uneconomic work doesn't pay. The only reason for adopting labour intensive practices is social, to create short-term income-producing labour for the unemployed.

In addition, it is worth reflecting that most labour intensive work is unskilled. The successful economies of the Orient should teach us that we must first develop skills (which means concentration on education in its broadest sense) and only then will we have some hope that the worker will add value in what he does.

Implicit in much of my argument has been an assumption that "good" technology drives out "bad", which I will call Lloyd's Law. It is the converse of Gresham's Law, well-known to economists, which states that bad money drives out good. Because of Lloyd's Law, it was not necessary for many towns in South Africa to invest in gas distribution – by the time they had even thought of it, the superior technology of electricity was at hand. When we came to add television to our broadcasting network, there was no need for us to follow the crude colours and resolution used by the US and British systems – we had PAL, and all the benefits it can bring. Because our telecommunications have been designed around the computer age, we can afford to be heavily into ATM's, and are the envy of many visiting Europeans.

These are not proofs of my Law, just illustrations of its obviousness. However, before you accept it too glibly, consider the awful implications for "appropriate technology". If you had a choice, would you opt for water from a tap, or would you like to walk down to the dam filled by the windmill-driven pump? These are the sorts of choices being placed before our Third World, and it does not surprise me in the least that the alternatives are rejected.

For South Africa, the final note of hope which has emerged from this study is that the very proximity of the First and Third Worlds will almost certainly aid the rate of development of the Third World component of our land. In an earlier section I noted how awful the slum areas of London were less than three generations ago. The First World War intervened, and then Britain started to build. At peak there were over 500 000 new houses being built per annum, and within a decade the whole problem had been resolved.

We tend to underestimate the speed with which we have moved in creating the social infrastructure which we now take for granted. The superhighway has not always been there, for instance. At one stage, Thomas H. Macdonald, the Chief of the US Bureau of Public Roads was so bold as to predict (Scientific American, 1987) – "The main highways of the future are pictured . . . , as broad, unobstructed surfaces over which traffic can flow smoothly with safety and comfort. At the speeds we can now foresee, we will want a 22-foot road for two-way traffic. Its surface will be consistently smooth and non-skid, and it will be so designed that at no place will the traveller suddenly encounter the unexpected. Where the traffic is so heavy that two lanes will not carry it, there will be four-lane roads consisting of two lanes on each side of a center parkway." This was a public pronouncement in 1937, exactly 50 years ago.

The First World can move fast to create the infrastructure it needs. Thus we can develop our own Third World far sooner and far more efficiently than if it were alone. Our technology can bring the two Worlds together more closely and more quickly than our critics could ever believe.

The proximity of the First and Third Worlds is unfortunately seen as a threat to the First World in South Africa. However, we have seen that technology actually drives social change far more positively than many care to think. I believe in the strength of technology in general, and in the strength of our local technological resources in particular. What too many see as a threat, too few see as an opportunity. I hope I have been able to show that we need not fear. If we have confidence in our abilities, and if we have the statesmanship needed both to view our country as one and to persuade our fellow South Africans of the correctness of our view, then we have real hope that all South Africans will enjoy in harmony the fruits of the First World which we technologists can create.

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