TECHNOLOGY ASSESSMENT IN THE CITY

The Urban Ecosystem

From the beginning of man's exploitation of knowledge and technology he has improved his own chances for survival and reordered the environment to suit himself. In most instances, these dual goals have been accomplished at some price to the environment.

There is no evidence that in his early exploitation of technology man was any less cruel and senseless than he is today. Early history supports the hypothesis that man evaluated each new discovery in terms of its death-evoking potential to his enemies and his own survival. Later, as knowledge and particularly as language developed, technology as a means of producing wealth predominated. With every advance in technology the planet was further plundered as its wealth was discovered, and these discoveries led to the costly political struggles in which the newest technical devices pitted man against man for control of the world's wealth.

Today, the United States is extolled as a leading example of technological development and enlightenment on the one hand, and, on the other, is castigated for using an unfair share of the world's resources to sustain that standard. Japan is emerging as a high technology nation through the exploitation of scientific and engineering development, but the price is high in terms of stress-induced mortality and in pollution. Simultaneously, Japan is enjoying a standard of living unprecedented in the Orient.

The most technically advanced nations—West Germany, the United States, and Japan—all have the most severe pollution problems as well as the highest standards of living. But it can be argued whether the cost in ecological impairment is justified by the benefits derived from this highly industrialized condition.

The onward rush of technology raises a number of serious questions for the future. Where will new sources of energy come from to drive the machines of technology? Will the water supply last? Will there be enough minerals to satisfy technology's insatiable appetite? Will the continued pollution of the air make city life untenable? Will development destroy all of nature? Will the nation be paved from coast to coast? Will the wilderness or any natural area survive? Will cities perish in their own waste, filth, and crime?

Technology did not release man from the

natural ecosystem but involved him in a new one. Biologically he changed little but he modified his environment through the use of tools. The ecosystem concept did not change either but new factors were introduced in the form of man and his tools. Man's ecosystem does not differ from other ecosystems, except for the proliferation of technological devices that directly and indirectly aid man in ordering and controlling his environment and producing wealth. Thus, technology in the hands of man became a new, potent ecological factor.

As an organism, man responds to the same biological and physical factors as always but modern man has altered the human environment with his technology and this has affected him. For example, vaccination against smallpox and the pollution of rivers with agricultural and industrial wastes are two diverse ways in which technology has altered the human environment.

Man's basic requirements for survival do not vary from place to place nor from time to time. As a biological organism he is a mammal and has mammalian requirements—he must obtain food, reproduce and avoid predators, provide protection for the young until they reach the age of reproduction, and so on. The presence or absence of technology allows man to control the environment and provides a high potential for its destructive degradation. As technology has increased, man's control over the environment has increased and so has his need for energy.

Man has always been part of an ecosystem. In earlier days he lived and died in a predator-prey relationship, but with the advent of technology, man, for the most part, freed himself from his predators. Once free from predators, man could concentrate on improving his chances of survival by husbanding food—either through hunting or agriculture—and by securing his environment and modifying it to suit his needs.

Primitive men in primitive societies lived more harmoniously with the environment. Having no way to change the environment, they adapted to it and lived in harmony with it. Even so, primitive man may have altered environments to some extent. Setting fires, for instance, may have been a simple method for altering environment, particularly in the prairies, the onset of agriculture. But it remained for modern man with his technological devices to dramatically alter the environment, and in so doing he has psychologically attempted to place himself outside the ecosystem and ignore the effects of his technology. Modern man must recognize that he is an indivisible part of the biosphere, that everything he does affects it, and that the enormous quantity of energy available to him is a potent factor that cannot be ignored.

The communities of man fit all the requirements of ecosystems. They have elements that stabilize them and those that destabilize them. Communities of man that are diversified tend, like communities of plants and animals, to have great stability. Those that are simple tend to be unstable depending upon the factors that impinge upon them. One need only compare a great city with many sources of employment and wealth production with one-industry towns to recognize the relationship between the ecosystem of man and the ecosystem of other organisms. Ecologically they are quite similar.

The principle of ecosystem dynamics is that ecosystem stability depends upon the flow of energy into the ecosystem, and as the system optimizes its use of energy it becomes stable. All ecosystems are either at a steady state condition and have great stability, or they are approaching the steady state, or they have passed the steady state and are going into a decline. The steady state represents the balanced use of the energy available to the community in relation to the factors influencing it. In exactly the same way that equilibrium condition makes possible the thermodynamic analysis of energy systems, so the ecological steady state makes possible the analysis of ecosystems. The ecosystem steady state is the thermodynamic equivalent of "balance of nature."

A number of prerequisites for ecosystem analysis are necessary. The first is to recognize the steady state when it is achieved, and the second is to recognize developmental stages on both sides of the steady state. It is necessary to understand that as long as uniform or stable physical conditions persist, the ecosystem will reach and maintain steady state in relationship to those factors. And it is equally important to recognize that, in addition to the usual factors, i.e., sunlight, rainfall, wind, temperature, water, and the seasonal distribution of these factors, man, even without his technology, is an important ecological factor. With his technology he becomes a formidable ecological factor for both good and evil.

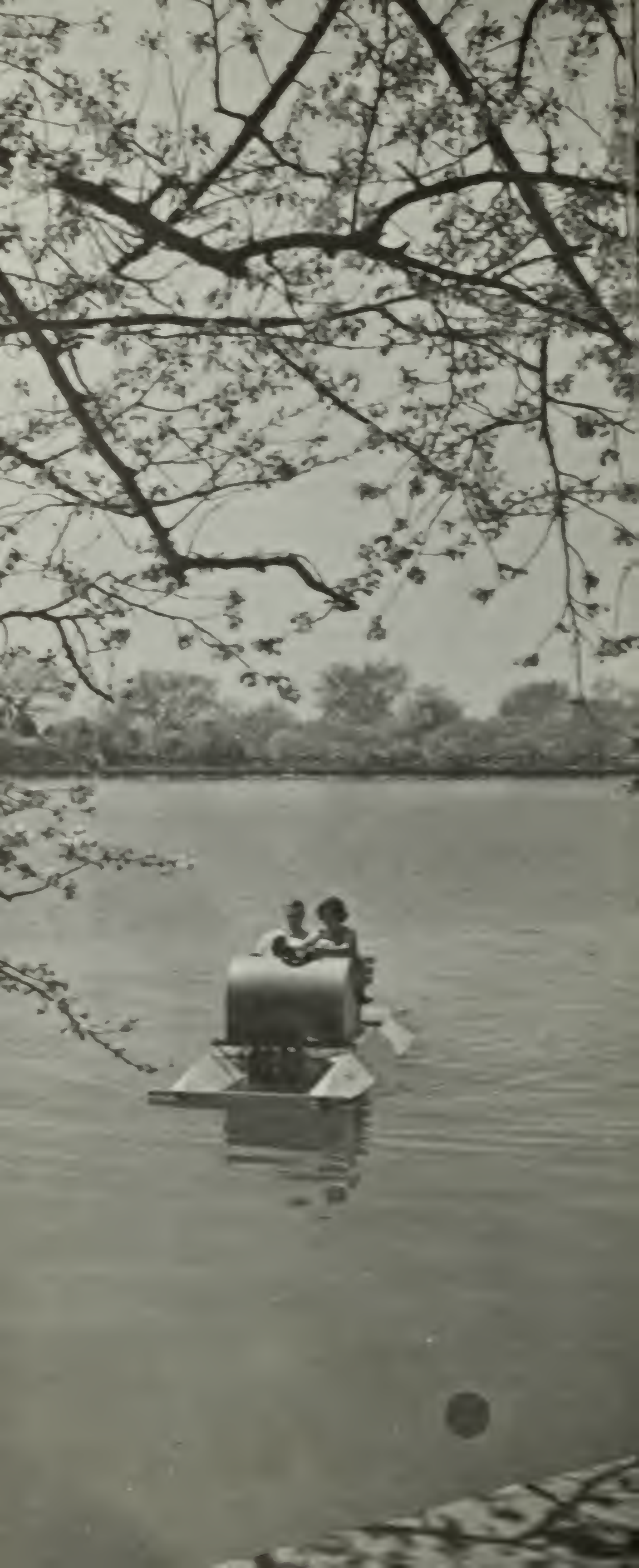
Man can move mountains, pollute lakes, replace the tall grass prairie with corn, and convert the eastern deciduous forest to farms and finally to a megalopolis. It is interesting to consider that in the tall grass prairie, tall grass—big bluestem or Indian grass—was replaced by another tall grass, corn, and that the ecosystem that developed is as stable as the ecosystem that it replaced.

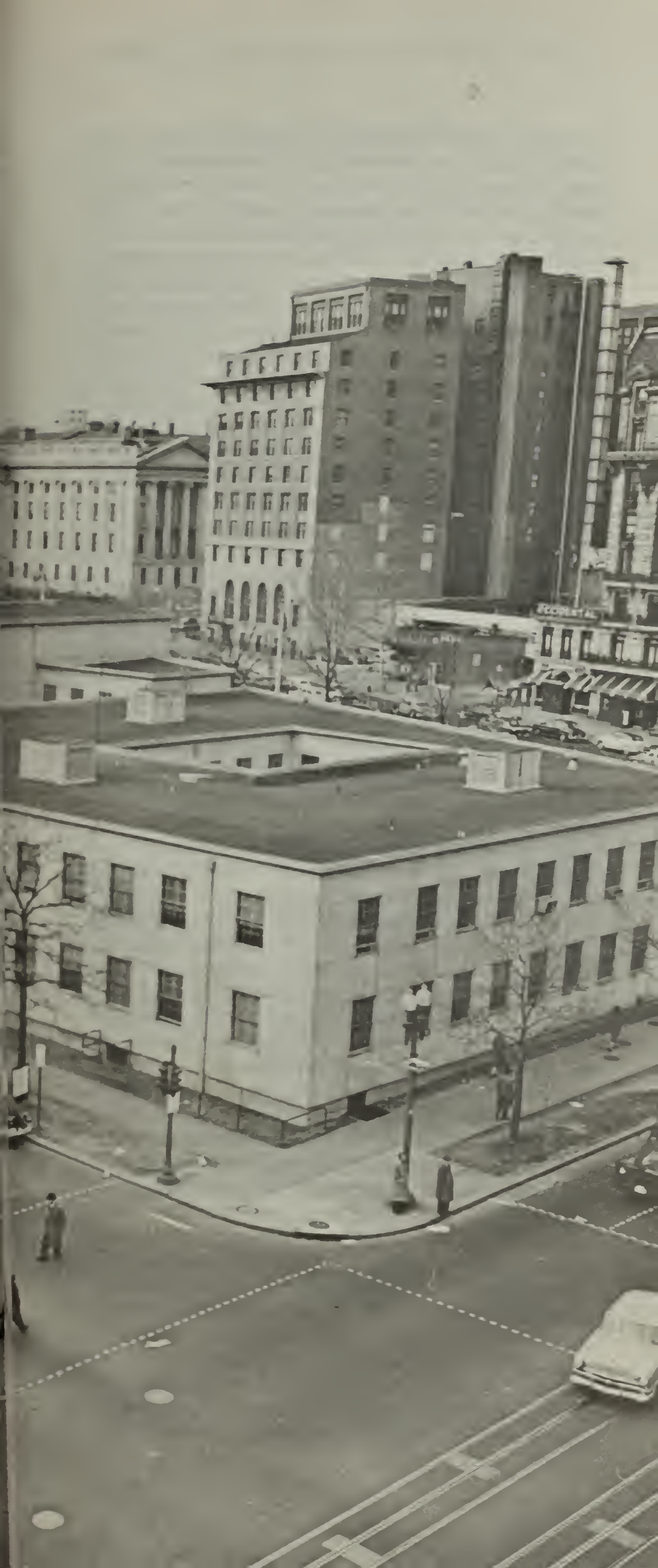
However, there is an important difference. The ecosystem of corn includes men, tractors, energy sources such as electricity and gasoline, seed producers, grain storage bins, transportation systems, and other paraphernalia in addition to the sunlight energy that falls on the cornbelt. In short, a corn ecosystem requires other kinds of energy in addition to the sources that are adequate for the natural tall grass prairie. The corn crop is the result of all these inputs—capital and manpower, sunlight, water, minerals, temperature, etc. If the fertilizer is withdrawn, if the tillage and cultivation and weeding cease, the ecosystem of tall bluestem and Indian grass would quickly replace the corn. Corn has been in cultivation so long that it is dependent upon man—tall bluestem and Indian grass are not.

In the eastern United States, man is abandoning farming as a way of life and these farms are reverting back to the deciduous forests from which they were developed. In Pennsylvania, for example, large areas are being rapidly overrun by resurgent eastern deciduous forests that are increasing at the rate of 1-2% each year. This does not mean that the economic value of this land is diminishing since it may have a higher value for recreation and for homes than it did as farms.

Since the communities of man are ecosystems, they stabilize and destabilize in exactly the same way as do other ecosystems. The factors that tend to destabilize ecosystems are those factors that lead to their simplification or to their degradation. The factors that tend to stabilize ecosystems are those factors that tend to increase diversity and variety. In reality, diversity and variety are changes in the way energy in the ecosystem is used. Ecosystems are essentially energy processing systems, and the fewer uses for energy there are in the system and the fewer outlets for its consumption, the less efficiently will the system handle the different forms of energy. On the other hand, an ecosystem with many levels of organization, where the products derived from processes are the inputs for other processes (preferably in cyclical fashion), becomes efficient in using energy because the same materials are processed over and over again using many forms of energy rather than allowing the energy to dissipate.

All biological systems recycle materials. When man does not recycle materials because





the use of new materials is "cheaper," the energy input into the "scrap" is irretrievably lost. Systems that do not recycle their products are less efficient, since new materials must continually enter the system and additional inputs of energy are necessary to operate these processes. In addition, the system will have lost the energy that was expended to produce the original product since the product requiring the input of energy is not being recycled. Rearrangement of economic priorities could minimize these losses.

When the steel industry recycles scrap a great saving is made because fresh energy that would be necessary to smelt ore in a quantity equivalent to the scrap is saved. In addition, the energy needed to mine the ore and the energy associated with all the additives that make steel are saved because they are already present in the scrap. However, in the utilization of scrap a different input is required, i.e., the energy necessary to collect the scrap materials and return them to the process.

However, since the origins of virgin materials are relatively few and often widely dispersed, transportation systems are required to convey the virgin materials to and from the processing plant and this balances economically with the reuse of scrap. But the economics of the use of virgin materials, particularly in the metals industry, is significantly enhanced by economic subsidization, whereas there are few, if any, economic incentives for the use of scrap. What is actually happening is that the energy input into the scrap is being dissipated, while new and larger amounts of energy are being expended to mine virgin materials.

If the same economic incentives applied to the use of scrap our industries would be recovering even small amounts and processing them profitably, rather than mining rapidly dwindling supplies of virgin materials. If the materials in a technological ecosystem were recycled—and recycling technology is well understood—only small amounts of new inputs would be required.

If we could evaluate technology in terms of its stabilization or destabilization of the ecosystems, both those dominated primarily by man and those not occupied or dominated by man, these considerations are enough to evaluate the worth of technology in the long-term survival of man and the city. And because man is concentrated in cities more densely than elsewhere, it is important that we take a thorough accounting of the effects of technology on city ecosystems.

The survival of man on earth as the dominant species in the biosphere depends to a large extent upon the health of the biosphere itself. In general, the large marine and terrestrial ecosystems are stable, having evolved over the millenia. They change but their normal change occurs in geologic time and in an evolutionary fashion. The seas and the forests and prairies, the tropical rain forests and deserts all play a part in the water, nitrogen, carbon, and other geobiological cycles.

Man with his technology has created revolutionary changes in the biosphere. Land used for agriculture has disrupted normal ecosystem processes. That same land, heavily fertilized, has brought about remarkable changes in the productivity of surface water as excess phosphate and nitrogen and other fertilizer elements enter the streams and rivers and finally the seas.

Industry has, slowly at first but with logarithmic increases in rate, polluted the atmosphere to the point where we must ask for how long air that supports human life can be guaranteed to be in sufficient supply in our cities and heavily industrialized areas. Pesticides and industrial pollutants such as mercury are pervading all nooks and niches of all ecosystems of the biosphere.

Man therefore poses a threat not only to himself but to countless other species of plants and animals that properly form the elements of the biosphere. Modern technology is beginning to demonstrate for the first time in the several-million-year history of man on earth that it is possible to bring about destructive, irreversible changes in marine and terrestrial ecosystems; changes that ultimately will alter the course of biospheric development. Man cannot destroy the biosphere, for to do so he would have to destroy all life on earth, but he can make life untenable for himself.

Disturbances in ecosystems tend to set them thermodynamically into motion. New balances of nature result from such disturbances, and these new balances of nature may be either desirable or undesirable, depending upon how they enhance or degrade life for man.

Industrial pollution, ecosystem destruction through any means whatever, on a scale large enough to upset the biosphere may be self-correcting if one of the consequences is the demise of man and/or his technology. If accommodation with biospheric dynamics is not achieved by man, man's technology probably will be severely limited before he himself faces extinction.

The principal problems faced by man the technologist are to continue economic growth by developing clean as well as cheap sources of energy and by feasible recycling where reclamation of materials is economically sound. Clean water and clean air must result from reclamation of the by-products of industrial and manufacturing processes. The present economics appear in conflict with this notion but that is because the present economics postulate abundant supplies at no cost to the environment for disposal of the "waste" of industry.

If "costs" to the environment are calculated into the disposal formula, and it is recognized that the medium- to long-term consequences of such disposal is degradation of the standard of living for man, the ecological "reclamation" of waste materials will become profitable indeed.

The effects of technology on man will be most influential where man is concentrated in the greatest numbers, and these places are obviously the cities of the world. Since cities are biological communities of man, it follows that the biological requisites for proper ecological living must be fulfilled or the principal inhabitants of the community will suffer.

High-speed transportation cannot be the substitute for man negotiating his immediate neighborhood. To be viable a neighborhood must be accessible easily and comfortably with little waste of energy or time. Neighborhoods structured to accommodate high-speed, individualized traffic flow are inaccessible to persons on foot and can be negotiated only at relatively high cost in equipment and energy requirement (while the human organism converts its excess energy substems to lipids instead of chemical-mechanical power).

High-speed, individualized transport, therefore, has a tendency to destabilize ecosystems of man because of inordinate energy requirements, the large areas needed for maneuvering and storage, and the effect it has on dispersing the community. The latter results in difficult person to person communication and spatial distribution of housing units that are only inefficiently serviced with water, sewage service, and other utilities.

High speed mass transport on the other hand (where there is no need to store the transportation elements in the neighborhood) tends to stabilize the neighborhoods into the larger complex of the city ecosystem. Mass transit is more efficient and less costly to operate per passenger mile, and while it does not provide the "absolute" freedom claimed for individualized transport, it provides freedom of access to all parts of cities for all inhabitants regardless of economic or physical status. Children, old people, and the handicapped can travel by bus or metro or train but only a fraction of the total population has access to individualized transportation. In other words, mass transit serves the total community in a way that individualized transport cannot, and thus its effect upon the community is a stabilizing one.

Communications as technological activity have profound effects on the biological community of man. First, although direct communication may not be practical among all inhabitants of the neighborhood, to maintain the integrity of the community it is necessary that its members recognize each other. In the design of human communities an essential element to stability is the opportunity for individuals to contact other individuals in the normal course of life in the neighborhood. The compactness of ancient cities had this property to a remarkable degree. The stranger in the community was instantly recognized and behavior was influenced accordingly. In many modern communities, especially high-rise construction where ratios of public to private places are inappropriate, there is little opportunity for personal interaction and those that do result are hostile and dangerous. Such places are not fit communities biologically or technologically.

The telephone, radio, and television have stabilized the higher-order structured ecosystem, uniting neighborhoods, towns, and cities into a common communication fabric. Their influence has been so profound in this respect as to cast some doubt on the validity of an ecological equivalent of the community for man. Telecommunications have made it so easy to communicate with individuals that are far removed from the immediate neighborhood of either work or living that bonds between

remotely located individuals may be much stronger than between those living in adjacent houses or working in adjacent offices. But ecological security, comfort, and well-being of the individual are dependent upon other members of the community within his or her physical proximity. The telephone, radio, and television, insofar as they undermine the ecological fact of life, tend to destabilize human ecosystems. As means of communication within community elements they are necessary for efficient living in the community; between communities already ecologically sound they tend to stabilize both the immediate community as well as the higher-order ecosystem of the city, state, or nation, going so far as to produce what Marshall MacCluen has called the "global village."

Radio and television, more than any other technological devices, have made it possible to synchronize the activity of communities and in this respect they have been great stabilizing influences. Even catastrophes on a national scale have been mitigated because instantaneous communication was possible.

The overall health of the biosphere, the destabilization and degradation of the marine ecosystems and the large terrestrial natural ecosystems, is perhaps more important to the survival of man on earth than the destabilization of human communities. The destabilization of communities of ecosystems tends to be self-correcting. If man's destabilization and degradation of the human ecosystem is not reversed in the future, he may not survive in sufficient numbers to be the great destabilization factor of which he is capable.

Factors that tend to stabilize and destabilize the human ecosystem can be demonstrated by the example of public health services that decrease death rates, e.g., vaccination for smallpox. Factors that promote health and decrease the death rate are considered beneficial, but eventually they bring about increased population, at which point other causes increase the death rate. If birth rates exceed death rates as they have since man acquired technology, populations increase until other factors limit them. These factors at present are considered to be food supply and the resources needed to run technology—particularly energy sources and high technology materials. At the present time, no end is predicted for global population increases although population has slowed or stabilized in some places, and in others massive efforts are underway to effect limits to population growth. The fact that populations cannot increase without limit is a biological truism. The question for man is, will the stabilization of population be left to chance or can technology be applied to solve this problem as it has been applied to solve so many others? It is inevitable that populations will stabilize. Will the process be orderly or chaotic? Population crashes are well known biological phenomena and are well known in human populations as well. The counterbalancing ecological factor in population control is not to reintroduce smallpox to control population, but to adjust birth rate. If decreases in the death rate are accompanied by decreases in the birthrate an ecosystem steady state is preserved.

The development of the city, i.e., the factories, shopping places, highrises, and skyscrapers, has had both stabilizing and destabilizing effects. The highrises and skyscrapers and factories, in segregating and isolating the work function of man from his other life functions, have distorted the human community. Factories that produce pollution have destabilized and degraded the ecosystem, and the effects of highway construction have been both good and evil. The highways have cleaved heighborhoods, destroying viable human communities in the name of progress. Urban renewal has destroyed viable human communities and replaced them with great technological works that, by omitting human activity around the clock, become dangerous to human life. Mass transportation stabilizes human ecosystems because it encourages the development of neighborhoods and work areas of the cities, where space requirements are governed by the size and energy requirements of man rather than the size and energy requirements of the automobile.

Destabilized and degraded human ecosystems are characterized by substandard housing, crime, economic dependence, poor quality services, poor health, disease, and infant mortality. Factors that tend to stabilize the city are well-developed neighborhoods that have the characteristics of good biological communities, diversified income sources, many opportunities for employment, economic independence. low incidence of communicable diseases, and lowered infant mortality. Great numbers of voluntary associations, each capable of defending the interests of its group, also stabilize human ecosystems.

An environment in which privacy is assured while public places are under surveillance tends to invoke an attitude of self-discipline that aids in the prevention of crime and acts of violence against property and people. The neighborhood constructed so that the interaction of neighbors is easy to accomplish reduces the risk of developing an anomic society in which a woman could be murdered while persons living in the isolation peculiar to a wretchedly planned city were not motivated to help, not even to the extent of calling the police from the safety of their isolated citadels.

Malthus' predictions on population forecast the conflict between biological need for food and the technological ability to satisfy those needs. His predictions, although they have not come true, have had a tremendous influence on economics and consequent human welfare, and it is important to recognize why Malthus was wrong.

The base that Malthus used for the growth of the human population was the reproduction potential of man which is logarithmic growth. His base for food production was arithmetical, based on increases in cultivated land. Malthus calculated that populations would increase approximately according to the compound interest rate, but the food to feed such a population would increase only as additional acres of food were put into production. He assumed that there would be a constant yield of food per acre per year and his calculations proved to him that there was not enough area on the surface of the earth to develop the agriculture necessary to feed a population that was increasing geometrically.

We now know that plant and animal reproduction is also geometric and that modern agriculture has increased yields of foods significantly at the same time that acreage is being reduced. That is to say, 1/7 bushel of corn planted per acre may produce 10 bushels to the acre; 25 bushels to the acre; 50 bushels to the acre; 100 or 200 or as many as 350 bushels to the acre depending upon the factors that surround the husbanding of the original 1/7 bushel of corn.

Malthus also failed to take into account the fact that the increase of knowledge that creates technology in the first place is also a geometric function. While population continues to increase geometrically, today there is the possibility for food also to increase geometrically. The rates in both cases may differ but, most important of all, our knowledge of how to control the growth of population of humans and animals and food plants is increasing geometrically.

This is not to imply that the population is not or will not become a problem, not to deny that large numbers of people will die of starvation or related causes in certain areas if population is not controlled. But it does mean that the cataclysm that Malthus predicted has not occurred because all the factors involved are geometrically related functions and their animals; and finally of mechanized tools—steam and internal combustion engines, electrical motors, physical, chemical, and nuclear energy.

During the rise of technology, man developed cities where the work is done and where energy conversion occurs. With the transportation of materials, fuels, and energy, the cities have become the principal places of energy utilization. The simpler the city, the less need it has for energy. The more complicated the city, the more energy it will use. The more diversified the energy sources, the more stable the system; the fewer sources of energy, the less stable.

The power grids of the nation are rapidly becoming one. The New York City power blackout occurred because the system was dependent upon relatively few alternative methods of transmission. Once the grid system broke down, large sections of the northeast were blacked out, with serious consequences. Ecologically, it was a lack of redundancy that contributed to the failure of transportation of power to cities.

Redundancy is a major ecological factor in ecosystem stability. The power grid, if it is to remain effective as it grows and encompasses all of the United States, must be many power grids. It must have redundancy built in in every conceivable way so that if one part of the system fails, other portions will automatically continue to function.

The history of the city as the transformer of energy illustrates the congruity of the city and other natural ecosystems. As the cities have increased in complexity they have done so because of increased knowledge of energy transportation—mechanical, chemical, physical, and nuclear. An analysis of energy utilization and the effects of energy utilization upon the stability of ecosystems provides the only logical basis for technology assessment.

In studying the achieving society, electrical energy production is used as the index of achievement. Highly developed nations have high energy production and consumption. Those with the greatest energy consumption also consume the greatest amount of the world's raw products. In evaluating technology, the most important question is: What is technology, old or new, doing to the natural ecosystem of the world? For centuries there was little concern for ecosystem degradation, whether of man or nature, but recent trends in technology have resulted in instability and degradation of the human as well as the natural ecosystems that threaten the very existence of technological man.

The vast consumption of energy needed to power individual automobiles is wasteful. In terms of efficiency of use the automobile not only wastes energy because its energy-converting process is inefficient, it also pollutes and degrades the environment and disperses the human community. Water, electricity, gas, and sewage disposal become inordinately expensive due to the low density of the population served.

High speed transportation can and does have a stabilizing effect upon human ecosystems by increasing the rate and amount of goods and people moving in the course of business. The automobile is self-defeating and detrimental when it is made the basis of transportation in the neighborhood communities of man, for it distorts the community out of proportion to the size and energy capability of man himself. Moreover, it has a tendency to inhibit the movement of the non-driver—the aged, the young, and the infirm. Telephone communication knits together the community and is a stabilizing influence.

Pesticides simplify ecosystems making them prone to invasion by unwanted organisms. This disadvantage must be weighed against the possible gains. Pesticides bring about a reduction of ecosystem diversity and the stability that is the hallmark of ecosystem health. The effects of technology can be measured against that standard.

The computer, the extension of man's brain, is capable of processing the voluminous data that must be evaluated, and the computer is ready and waiting. We need to understand that technology assessment is an ecological problem. Specifically, it is the problem of evaluating the use by man of energy and the effects of that energy upon the ecosystems; the primary one of these is the city.

—Theodore W. Sudia

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