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Material Resources

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EDITORS

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II

MATERIAL AND TECHNOLOGICAL DEVELOPMENT

MATERIAL RESOURCES

by

RICHARD L. MEIER

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1. *Introduction*

The background for this submission is significant. The Engineer's Joint Council in the United States has had a continuing concern about engineering education, but it has been particularly alarmed about the consequences of the narrow outlook of engineering designers and consultants when working overseas. Many quite obvious contributions to development were being missed or disregarded. The needed curriculum change can most easily be introduced as part of graduate study in engineering, since the transformation of engineering colleges into graduate schools of technology seems to be the most remarkable feature of the forthcoming reconstruction of American universities. Therefore a committee was established under the chairmanship of one of the men who worked out the formula for the Peace Corps, Professor Maurice L. Albertson of Colorado State University. Together this group created the concept of a new breed, the "international development engineer". A dozen social scientists and planners were brought together by the committee, infected with the idea, and commissioned to draft papers incorporating the principles that ought to be brought to the attention of young men with such aspirations.

The present contribution has to take into account the intellectual milieu of engineering as it is likely to exist in the early 1970's. Any straightforward description of trends in production and

consumption of natural resources, together with estimates of discovery and depletion rates, may be used to highlight the critical shortages of reserves of a key commodity (although the most thorough analysis completed recently by the Resources for the Future staff, failed to elicit any immediate crises) but it has little value to the designers of future technology. We need not continue to go over old ground merely to persuade a few recalcitrants.

One other feature of the future milieu is evident. Systems design concepts are due to become dominant in America in those places they have not yet done so. Systems language is the interdisciplinary *lingua franca* of graduate study in engineering. It will take some time before this approach diffuses to the developing countries where the applications are most needed. Nevertheless, the writer today must struggle to expose his thinking in terms that are compatible if not synonymous with systems concepts.

This prospect forced me to introduce subjects previously not germane to discussions of resources. I realized that engineers are most interested in hints of new processes, products, combinations of the two, and packages of them that can be fitted together as modules. The resultant installations should be demonstrably superior to their predecessors. But that calls into question the matter of *objective functions*. What should be optimized? What indexes shall be used for measuring performance? No

system is complete without them. When seeking answers to these questions, engineers encounter social scientists and planners.

One other constraint was introduced by the occasion for the paper. I could discuss resources, and the design of cities that consumed them, but not overall strategy. It was someone else's task (an engineer who became a top rank development economist) to lay out the most efficient way of putting together a program of projects designed to maximize the rate of development. Another took on the problem of producing food in larger quantities at lowest cost.

The specific hints concerning the new resource-conserving technology seem to be tossed out in a diffident manner. This is calculated to interest the enterprising technologist, because he can map the clues upon his own training and produce seemingly practical ideas very different from anything in the textbooks. Actually each of these has been checked for technical, economic, and sometimes even for cultural, feasibility. A larger number of less promising alternatives have also been tested. Therefore the direction laid out appears to be the best that can be deduced from the present body of literature and practice.

This direction is surprisingly impervious to the revolutionary impact of technical breakthroughs. Originally suggested by a review of the state of knowledge fifteen years ago, the quantity of new reports produced in the interim equalled all prior publications; nevertheless the theme has been reinforced rather than blocked and redirected. The masses must move to cities to have a chance at the good life, not away from them.

One last observation should be noted. Although a great deal of ingenious and significant technology needs to be crea-

ted, it is evident that at least for a long time to come the international development engineer will not achieve the mathematical elegance of his colleagues working with computers, solid state electronics, or aerospace technology. The sophistication to be sought in the conservation of material resources is that of empathy with other peoples and other professions.

2. *Resource development and use*

Although the amounts of land, energy, and other natural resource inputs required to maintain a man at adequate levels of living are declining,¹ indicating that technology is becoming more efficient over time, the overall demand for future consumption of resources exceeds still further the supplies available to countries endeavoring to develop. The principal reason for this paradoxical trend is that population growth has been accelerating in these areas.²

Action is being taken on the population planning front, but the reversal of trend will take some time.³ The conclusion could easily be reached that many countries are becoming so populous that the resources available per capita are too small to allow them to break out of the Malthusian trap (Table 1). However, such calculations are based upon output-resource use ratios for presently-recommended processes worked out in countries with plentiful resources. An assessment of possible resource-conserving technologies needs to be undertaken to discover whether a new path to economic development can be found which will cope with a greater population burden.

The best hope lies in the new knowledge acquired from the recent burst of scientific research and development. How will the additions to our stock of knowledge shift the projections? Does

it suggest a more economic path to industrialization, urbanization, and modern institutions than the historic route pioneered by Western countries? External economies obtainable from the close integration of large systems offer the most opportunities for increased efficiency. Perhaps the scale of the industry may also yield some sizable improvements in performance.

The properties of the overall population-resources-knowledge system must be kept in mind while engaged in explorations of possible paths. Consider the normal history of a natural resource, whether a mineral deposit or a living population, as in a fishery. It can be identified as a natural resource only when the state of knowledge reaches a level where the potentials for human use are evident. Effort and skill are needed thereafter to wrest it from the site and convert it into an acceptable commodity. Firms and institutions are involved in determining what admixture, form, shape, quality standard, and image shall be imposed upon it. The ultimate fate of the resource is to be found in widely distributed deposits of ash, rust, scale, shavings, shards, bones, and similar debris along with carbon dioxide released to the atmosphere. New knowledge about resources eventually requires a bigger dust-bin!

Some lasting effects can be identified within the human population notwithstanding. Ecologists point out that added resources for any living population (human included) causes the members to become more robust, then to fatten, and shortly thereafter to expand in numbers. Thus extra access to resources yields increased bio-mass. The human race is presently responding in that manner to resources discovered one to two generations back. However, the leading resource-consuming societies have now advanced

a bit further because the channel leading to bio-mass formation has been throttled by more widely diffused knowledge about birth control; new channels have been opened up instead which convert the utility of resources into enhanced social and cultural activity that leaves a residuum in the form of enlarged institutions. In popular cybernetic language, the negentropy of the natural resource is transformed into the negentropy of social order and into the patterning of symbols (recorded knowledge) at higher levels in the hierarchy of organization⁴. The exploitation of large systems potentials requires the synthesis of a "higher strategy" which overcomes critical shortages experienced in subsystems.

The central arguments justifying the need for a fundamentally new strategy can be outlined briefly as follows:

1. Resource levels per capita in most countries endeavoring to develop are found to be a factor of ten to a hundred less than those of countries which have already developed (Table 1).
2. Even a redistribution of the world's resources between the *have* and *have-not* nations would leave grave deficiencies. Thus countries with surpluses will not be in a position to meet critical shortages when they arise.
3. A number of countries without a significant internal resource base have recently stimulated economic growth at a rate equal to or greater than those with very rich resources. The prime examples include Japan, Greece, Italy, Malaysia, Formosa, Israel, South Korea, and Hong Kong. They have found a means of developing human resources in such a way they are enabled to seize opportunities in international trade.
4. The new path to economic development emphasized investments in education, community building, entrepreneurial organization, borrowed tech

Table 1. *Value of natural resources in less developed countries*
(dollars per capita, current prices)

Country	Popula- tion 1967 est. (millions)	Agric., forest and fisheries ¹	Coal reserves ²	Iron ore ³	Petrol- eum ⁴	Non-fuel, non- ferrous reserves ⁵	Hydro- electric power ⁶	Totals ⁷ (rounded)
China	750	10	655	80	30	14	10	800
India	500	13	410	120	3	14	6	570
Pakistan	106	16	5	—	1	—	5	30
Indonesia	105	—	11	12	150	24	1	200
Nigeria	60	70	33	—	75	6	—	200
Philippines	34	121	5	300	—	32	13	500
Turkey	32	110	37	7	—	12	6	170
Thailand	31	116	—	1	—	40	1	160
Egypt	30	37	—	5	21	2	15	80
S. Korea	29	19	590	25	—	38	—	700
Burma	26	81	—	—	4	47	60	200
Iran	24	13	—	—	3000	4	3	3000

¹ Allows the value of the resource (mainly soils) to be assessed at ten times exports in the last reporting year.

² The value of presumably minable coal was set at \$ 5 per ton.

³ Technology is changing. Many ores losing value. Sets price at \$ 5 for 55-6 % Fe ore.

⁴ Value at the pool is set at \$ 1 per bbl. of probable reserves. Prices have been dropping.

⁵ Market values of extractable metals, sulfur, and phosphates were summed up, but where no reserve figures were indicated we took ten times export values in last year reported.

⁶ Greatly reduced in value since 1965 due to improved economics of nuclear energy competitor. Now assessed at roughly the coal equivalent of ten years full operation.

⁷ Comparable totals for the United States and the U.S.S.R. are close to \$ 30,000 per capita, for Western Europe (except Italy) they fall into a range of \$ 1000-5000.

Sources: United Nations documents, Mineral Yearbook, and miscellaneous national reports.

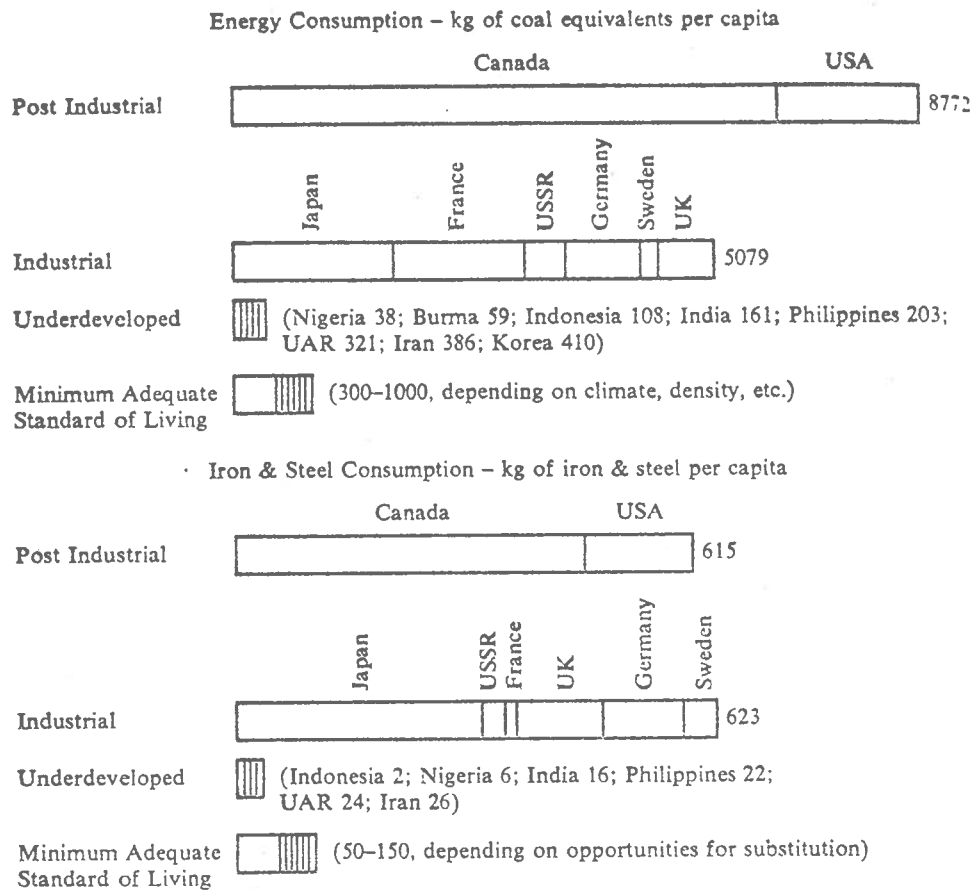
nology, and organized information acquisition, together with the evolution of life styles that save energy, time, materials, and foreign exchange.⁵

5. The design of urban environments should reinforce resource-conserving life styles, holding consumption close to the minimum adequate standard, preventing waste, and taking advantage of economies of scale. (Fig. 1 illustrates permissible levels of consumption as compared with Western life styles.)

6. The building of wealth-creating institutions requires headquarters areas (urban cores) in continuous contact with each other communication satellite relays, exchange of specialized persons, cultural borrowing, and transfer of recorded knowledge.

Very briefly, that is the program. Any strategy for development offering real hope for success forces us to consider wholly new and quite strange alternatives, each of them placing unique demands upon applied science and engineering. They seem to focus upon resource-conserving techniques that cannot be transferred routinely by consultants from the advanced countries but may only be elaborated in less developed countries around urban patterns of life adopted by the masses upon migrating to the city.

Curiously, none of the ideologies that divide the world today on issues of development policy seems to be pertinent. Both the socialist and the capitalist sys-



Source: UN Statistical Yearbook 1965.

Fig. 1. Indicators of present resource use compared to requirements for developing countries 1964 Estimates

tems have demonstrated that they can generate economic growth. The Soviet Union requires somewhat more energy to produce a unit of gross national product,⁶ and it has greater difficulty organizing the use of soil resources, but it has also prevented at great deal of wasteful consumption. Their respective preferences for public and private ownership of production facilities and of land are similarly irrelevant, because what matters for any modernizing economy is the presence of a vigorous, effective management. It must be willing to adopt innovations that pay off to the

consumer. Since innovation brings notable change in its wake, the management must be alert enough to shift its policies accordingly.

Large-scale developmental urbanism

Since virtually all of the richest resources, and almost all the surplus commodities in the countryside, are consumed in cities, it is easy to understand why the higher strategy for development must be concerned with the organization of cities. They comprise also the only place that surplus people can go in the

future. In the 19th century, large numbers could come to the New World and seek out virgin land, but the only frontier left now for the extra pair of hands raised on the very poor farm is to be found within the city.

The most demanding task for the cities is that of creating jobs productive enough at least to maintain the masses of immigrants at the subsistence level. Simultaneously they must instigate advances in efficiency that permit continuous improvement, at least up to adequate levels of living. In the course of this transformation the masses will become differentiated, skilled, organized, and opportunity-seeking. Cities must continue in this fashion to absorb all the dissatisfied rural dwellers until a new equilibrium between the modern metropolis and a productive agriculture-based hinterland is reached. At that time we must expect, as is done in Japan and Europe, that 90-95 % of the population will be found in the cities. Large urban regions, made up of constellations of cities, must come into existence to accommodate the influx, some containing hundreds of millions of people.

Industries in the new cities will have a very unfamiliar mix. We must expect strong pressures to economize on foreign exchange and to save natural resources, combined with a remarkable level of technological sophistication in the high priority, export-oriented industries. Such an emphasis is matched by a labor-intensive approach for the light industries (small machinery, microcircuitry, apparel, printing, plastics fabrication, etc.). As soon as the electrical grids have been set up, the power sources will employ predominantly nuclear fuels. The fossil fuels will be reserved as chemical reducing agents, as in steelmaking; or a source of carbon, as in plastics, rubbers, and fibers. Liquid fuels will still be needed

for aircraft and water transport. Food technology must be a far more important component in the societies struggling to develop, and water processing will assume a large role because water supply will on some occasions become the crucial resource input.

The design of industries in such a way that the use of scarce resources is kept as low as possible is already quite familiar to engineers. They are less aware, however, of the system-wide consequences of this effort.

The guiding principle in the design of resource-conserving industry and the urban utilities is to find ways of substituting information, computation, and communication for supplies of the scarce resource. Because the marginal costs of production of basic commodities and services from resources are expected to rise over time, only a few managing to remain nearly constant, while the unit costs of computation and communication are expected to decline sharply for decades to come, this rule is quite rational. Communication, the most fundamental of these processes, appears to be dependent upon a resource also – best described as *channel capacity* – but the measurement of the extent and richness of the resource on a global basis is still very much in flux. We know, for example, that a mountain top in line of sight of a metropolis in the valley has become the most valuable property of the city when built up with antenna, but what its value will be when the standing satellite arrives is uncertain. Possibly cities may eventually have to install resource management for their channel capacity to the same degree that land is managed today and water will have to be managed soon. At present channel capacity is given away, like land to railroads and homesteaders in the lands century, with only a few fees to pay for the

policing of rights. The limits are still not in sight so the substitution process can proceed for a long time to come.

The route by which substitution occurs is often quite roundabout. A few examples illuminate the possibilities:

A. A boiler using fossil fuel has a rather simple design, requiring a small outlay for instrumentation, quality control of inputs, and computing of optimum operation conditions. However a nuclear reactor designed for power production may allocate 10 % of the cost to instrumentation and uses 10^2 - 10^3 times as much process information. It happens also that the development of efficient nuclear technology adds uranium and thorium to be world's energy reserves, increasing the world energy reserves by a factor of one hundred or more, making it possible to supply energy to billions of people for centuries.

B. The dams in a developed watershed can be programmed to contain more water for the drought period when long range weather forecasts are made more dependable. This will occur when the earth's surface is covered with reporting stations, the data telemetered to a computation center via communications satellite, and the regional forecasts transmitted to control points for dam operation.

C. The yield of food crops can be increased several fold per unit area by educating farmers, investigating each constraint in production, rationalizing the distribution, and applying the best research results to the special situation. Thus a body of information intensive institutions must be created to enhance and stabilize food production, the primary investment being made in people and organizations with informed responses rather than electronic equipment.

The opportunities inherent in communications are so potent, each new and

growing technology uses more information transmission per unit of output than its predecessor. The control centers of these communications networks are to be found in the headquarters buildings in city centers. Marketing information is generated almost entirely in the cities or imported from overseas, so the programming, management, and distribution of the output of these new technologies is also an urban task. Thus, cities of the future in developing countries must be designed to expedite a rapidly rising volume of communication.

Investments in human resources are, as might be expected, more communications-intensive than investments in industry. They also seem to be more productive at the margin. The allocation of overall capital investment has been swinging strongly toward greater shares for education, and the countries accomplishing this transfer have prospered.⁷ The bulk of the investments in human resources takes the form of time spent learning useful tasks so that the time of task completion is shortened and error frequency is very much reduced. Human capital, then, may be regarded as a repertory of useful routines and concepts possessed by members of a society. The greater the repertory, the more adaptive the society.

Extra capital is created in the assembly of working groups, teams, partnerships, and face-to-face communities. Many firms, for example, have a value far transcending their investment in property and equipment. This "good will" item reflects a set of expectations built up over time that the firm will provide a convenient service at a reasonable fee. Public offices and agencies generate similar values but, since they cannot be sold like business, their worth is not readily appraised or entered into accounts.

Large corporations and complex social institutions, particularly universities, add even more to overall wealth-creating capability. "Institution-building" is a common means of enhancing collective wealth. As with all social capital, an institution is created by negotiation, the building up of mutual obligation, and a set of internal rules for economizing that take advantage of economies of scale. Large organizations are able to assign specialized groups to research and planned innovation, making possible the support of individuals who are equipped to contribute to the body of knowledge. New knowledge should be thought of as an addition to cultural capital.

The process of capital accumulation, especially in these poorly understood information-intensive forms, occurs almost entirely in cities, but not all cities. Those cities that require net subsidies to keep going are almost certainly taking on obligations faster than they create assets.

Planning for large wealth-producing cities

These shifts in viewpoint brought about by the potential productivity of human resources force us to rethink the plans for urban growth. The analysis must start from what can be done with the immigrants into the city.

A rural person, endeavoring to escape from grinding poverty in the village, should encounter an "environment that instructs" upon entering the city. Most migrants will be literate, but teaching materials for the self-improvement of the illiterate must also be prepared. Each should be able to use his home dialect or language at the same time he learns the official language. He should be able to hold onto most of the customs and rules for behavior trans-

mitted to him as a child, but add a number of others appropriate to the urban environment. Television, for example, can be an extraordinarily educational medium for people new to the city; the advertising can be most important of all because it describes how the substances on the inside of packages are actually used and what services are to be obtained at various addresses. Building a house of his own can also be programmed so that it teaches the whole family about construction, maintenance, property rights in cities, credit unions, and community organization at the very least. Making a living is the most difficult challenge of all, so a great deal of attention must be paid to on-the-job training.

As with advanced forms of educational organization, at least three paths into the urban milieu must be prepared, each of them gauged so that the learner is not overwhelmed and defeated, making him a drag upon the society. The fast track introduces the achieving migrants into part-time study, the libraries, and very soon into the most modern technology. They become the organizers and entrepreneurs as well as the technicians, often moving from the slum created by the settlement of urban migrants into the metropolis. The bulk will progress more slowly up the middle stream to the point where they establish a secure niche in the city, able to work at several kinds of jobs and produce quite a bit more on the average than their households consume. Some will be slow, bound to tradition, reluctant to venture out into the great city, suspicious of new foods and fashions, remaining either unskilled or highly specialized in a classical art. The developmental metropolis must find a way for them to live out their lives as productively as possible, without becoming an impediment to change.

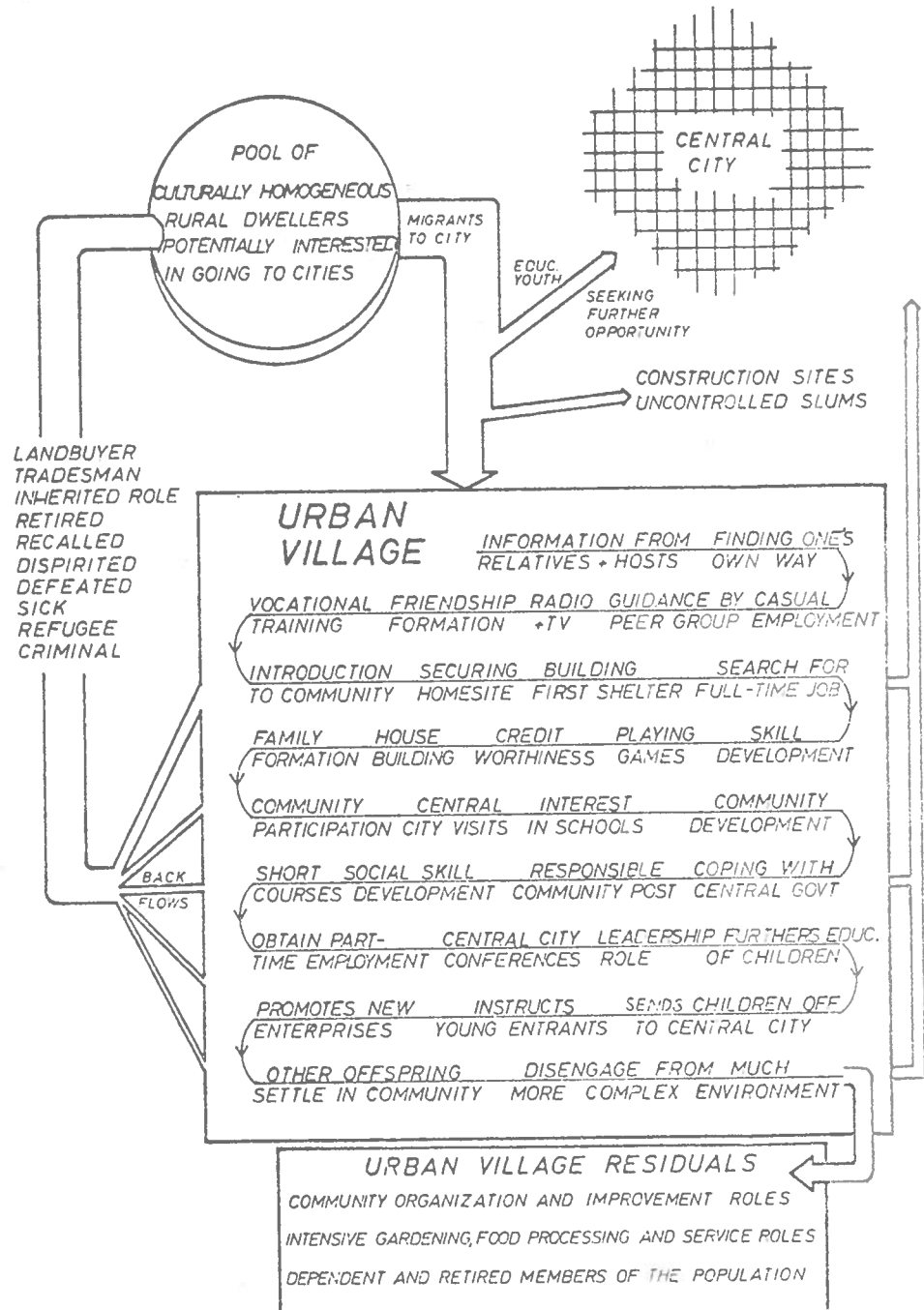


Fig. 2. The urban environment as a programmed instructional system
Sequence for creating productive citizens

The mechanism for accomplishing most of these ends is best described as an *urban village*. Land at the growing edge of the metropolis is allocated for a community made up of a single ethnic group speaking the same dialect. Access to industry and the central city must be available. Provisions for allocating plots, providing essential services (water, health, public order, credit, schools, etc.), and promoting self-organization are now widely agreed upon.⁸ However, the features of an optimum design, aimed to overcome the scarcity of key resources and accelerate economic development, are still not put together systematically. The sub-system affecting human capital development can be sketched out implicitly, leaving open the specific educational techniques to be employed (Fig. 2). Proposals for some of the others will be outlined more explicitly, although each region must develop significant variations.

The water use sub-system. The growth of every metropolis tends to outpace the development of the watershed that supplies its water. A dry year can bring catastrophic shutdowns unless controls over consumption have been introduced. Water conservation requires planning for repeated reuse of the water. Three qualities of water may be recognized, and small processing units must be established in most urban villages for upgrading the poorer qualities. A feed-back system can be readily assembled from as yet little-used technology suited to sub-tropical and tropical climates (Fig. 3). A "water watcher" in every precinct would maintain equipment and prevent waste in addition to other neighborhood responsibilities. A variable price for water, particularly when scarcity threatens, might help conserve this commodity.

Operation of the water use sub-system makes up only a small share of the to-

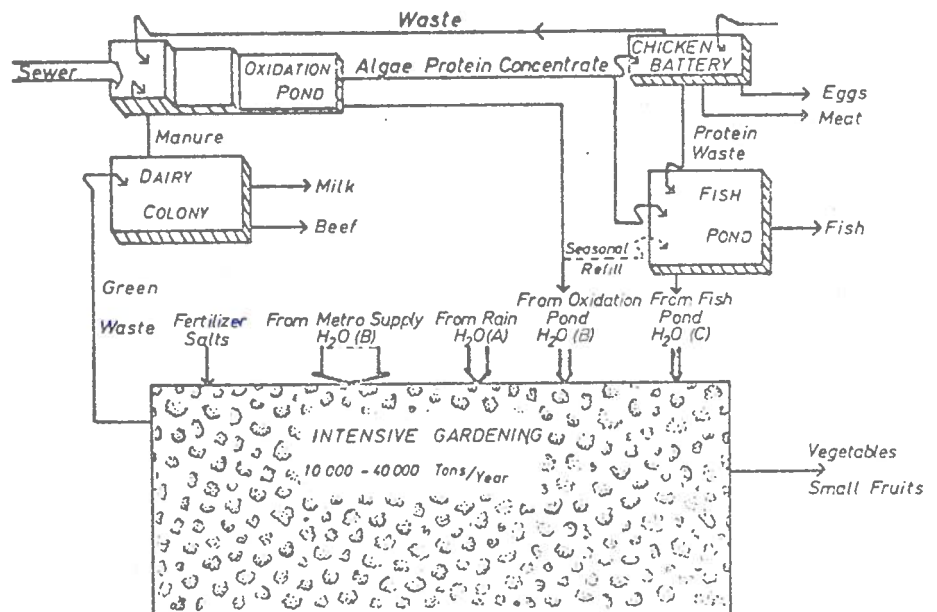


Fig. 3. Production of perishable foods in urban village (Population up to 35,000 persons)

tal cost of living at levels just above subsistence (perhaps 3–6 %), therefore it does not pay to invest very heavily in equipment. However its involvement in food production, which would be partially dependent upon waste waters, allows for some refinement in design and construction.

Food production and distribution subsystem. Food will often become critical during the course of development, so high priority will be given in cities to the building up of several sources of supply. Enough insecurity is likely to remain so that an equitable rationing system must be established. The ration normally includes cereal products, pulses, cooking oil, and sugar, all of which must be imported from a distance by the city. Subsistence levels for a working population amount to about 500 g./cap./day.

Perishable foods – milk, meat, fish, vegetables, roots, fruits – pose a very serious problem, because their consumption increases very rapidly as people's incomes rise above subsistence levels. Transport costs and spoilage can be greatly reduced if very intensive food production can be carried out within the environs of an urban village. An integrated sequence can be proposed which extracts the nutrients from human and animal wastes, utilizes waste waters, and is able to produce a wide range of foods in exceedingly high yields. Each operation can be designed so it contributes significantly to the efficiency of one or more of the others but remains labor-intensive.

Aquaculture, an approach that is just now becoming technically feasible, can produce four to twelve crops a year of potatoes, yams, Chinese cabbage, tomatoes, peas, eggplant, melons, etc. using synthetic fertilizer and allowing none of it to become locked up or decomposed by the soil. Current licensed designs are

relatively automatic,⁹ but a labor intensive design will somewhat reduce capital costs without introducing risk, and estimated costs of production are 10–30 % less than current bazaar prices.

Algae culture based on synthetic nutrients can produce protein suitable for direct human consumption, but a great deal of investment in its commercialization needs to be undertaken in various tropical and subtropical environments.¹⁰ The explorations in the underlying fundamental science are now relatively complete. Sewage-produced algae would be fed to chickens and fish (cattle do not need the protein) according to minor modifications of existing art in these forms of husbandry (Fig. 3).

Altogether, about two thirds or more of the weight and at least a quarter of the caloric intake of the urban diet can very likely be produced economically inside the city itself using present knowledge. Communications investments could contribute to efficiency here as well, since persuasion through mass media should develop tastes for the high yield crops in greatest supply.¹¹

Transport modes. Once cities begin to get larger than they are today, the greatest threat to their aspirations is that of congestion. It could cause a complete breakdown in the flows of people and goods. Urban transport is the most capital consuming utility, and its improvement requires the most careful planning. Any significant population of automobiles cannot be tolerated within resource-conserving urbanism. The wasteful uses of land and of capital are more important reasons than the effects upon the atmosphere for keeping automotive numbers at a minuscule level. Therefore, although the urban villages may be connected to the central city and industrial estate initially by bus and truck, plans should be made for displacing these

vehicles by economical forms of mass transit. The locations of urban villages should be chosen so as to minimize the costs of moving passengers and freight.

The central city may quickly become fully electrified, with cabs and buses depending upon nuclear-derived electric power. Bicycle scale vehicles will provide the best mode for short trips off the mainstream movements. Some of these will be propelled by light engines, as in a number of Asiatic cities today. The motorized cycle will be quite popular around the urban fringes.

Airlines will be many times more important than at present. Many of the exports from developing cities to the rest of the world will find the airlines offer economical means of exit. Indeed, almost everything valued in excess of \$5 per kg. is likely to move by this mode. However, as a megalopolis comes into being, the air space may well become saturated. Then a high speed "New Tokaido line" or tunnel transport mode will have to be installed for intramegalopolis trips of 25-300 miles.¹²

Water transport modes have an important future also. Heavy freight would be barged as much as possible. Intense shoreline use for recreation will give priority to passenger ferries and resorts on floating marine structures (spar buoys and platforms) of a kind that are just now being considered and promoted in developed countries but will be still more important to large new cities due to the shortage of open spaces the latter anticipate. This capability for movement, combined with those introduced earlier, suggests a continuous urbanization at the shoreline wherever the topography and the floodplains permit. Long beaded strands of coastal urbanism have not come into being earlier mainly because the expense of the control of congestion has been so great.

Similar sub-systems for the developmental metropolis can be constructed for communication, power production, several kinds of manufacturing, construction, health, religion, recreation, and other sectors. The close links between them and those already described are already evident. The designs of these also must of necessity be vastly different from the prototypes found in countries well along in the path to development. A large number of possible technological improvements in the various sub-systems deserve investigation.

What is to be optimized?

Technologists need objective functions before they can complete the design of a resource-using project. Ends must be agreed upon before the means can be chosen. In the foregoing brief description of possible resource-conserving combinations for urban life all the common objective functions were implicit, but they still left a number of choices open. For these a few relatively new development-related ends can be employed. They are taken up below roughly in order of importance for the resource-poor parts of the world:

Nation-building. The need to create an effective government, capable of functioning as a nation among nations, draws heavily upon the pool of partially developed human resources. It requires also a national capital linked up with other nations by airport, harbor, and telecommunications, a police force capable of supervising exits and entrances at the boundaries, a constitution and an administration of law, the nucleus of a civil service, an educational system, and a tax collection capability. Usually, however, the greatest need is more subtle, such as that of unifying the disparate language groups or tribes by means of enhanced exchanges so as to create a nationa

entity, stabilizing a currency, or developing an export industry. Resource development projects are backed predominantly for political ends, but these ends need to be reformulated for the designer as a long-term goal rather than the outcome of political bargaining for short term gains by special interest groups. Generally speaking, nation-building ends will be achieved if communications barriers of all kinds are reduced and loyalties of the new generation are transferred from traditional social units (tribes, communities, extended families, etc.) to images of the nation (flag, ruler, constitution, party, insignia, monuments, map, language, school, etc.). Nation-building is also advanced if modern forms of local organization (co-operatives, corporate firms, voluntary service associations, etc.) can be undertaken, if traditional forms of wealth are reinvested rather than hoarded, and if the participation in policy making increases both by the number of persons and the range of minority groups given a voice.¹³

Economic growth. The implications of this criterion are fully elaborated in textbooks on economic development. Unfortunately engineering economic calculations leave out of account the spillover economic effects of education and training (investments in human, social, institutional, and cultural capital). However, these non-market benefits are increasingly taken into account in bargaining between firms and in choices of project mix by government planners.

Social justice. Most governments will agree in principle that as many people as possible should be raised from subsistence to a level of adequacy, permitting them to participate in urban life without physiological constraint, as quickly as possible. This criterion implies that virtually all housing, transport, food processing, and utilities would be installed

at the minimum adequate level, and very little at levels of affluence accepted in developed countries. Incentives for the privileged classes take the form of enhanced status and more extensive services but not material consumption. In most instances this approach to design implies the implementation of a revolution that has already occurred on the ideological plane but has not yet transformed the social structure. Affluence is moral only after everyone has an opportunity to achieve adequacy. However most of the non-renewable resources will have been depleted by that time.

Social interaction. If communications are to be used to substitute for the scarcest resources, an enhancement in social interaction results. More time is spent in public affairs, cultural participation, and in the acquisition of useful information. The number of social transactions (messages, trips, conversation, purchases, agreements, items read, etc.) must continually increase. Any interdependence that overcomes earlier divisions in the society will enhance political stability and reduce losses due to internal conflict. The purpose of a city design is to expedite these social interactions.

The city and its immediate hinterland make up a natural region. If the foregoing criteria are applied in the course of regional planning, and if the leadership is effective in gaining cooperation, then substantial self-sustaining growth is expected to get under way. Urban centers create income or surplus, much of it immediately invested locally, but some will be distributed to the poor immigrants struggling to establish a foothold in the city, and more will be spent on projects in the hinterland – most of them for developing indigenous resources.

Much of the added wealth in the hinterland will migrate back into the city as investments in securities, insurance,

real estate, and in the form of education of youth taking their studies in the city or carrying their newly acquired skills with them to the city in search of opportunity. Thus a circular flow between city and hinterland builds up increasing volume over time. Managing this flow requires that leaks to the outside be counterbalanced by an influx of investment or aid from the outside.

A truly effective urban center should produce 12-15% more income each year, a level not as high as the most developmental cities in the past, but still more than the average in the most rapidly developing countries. The increments make it possible for urban organizations to go out and pursue opportunity actively, seeking useful workers as well as promising projects. Within a few years, these additions to the modern economy should produce additional increments of income. Thus an acceleration, or lifting, action is created, where an "engine for development" made up of collaborating institutions pulls a population out of poverty. A resource-conserving design for urbanization is necessary to the functioning of such an engine, but it is obviously not sufficient.

Expediting the transfer of technology

In urban areas, the process of accepting new technique or a new design that promises to be resource-conserving is very different from the village. Instead of individual cultivators and artisans being persuaded to change their ways and then assisting in the spread of the innovation among their counterparts in neighboring communities by means of the "demonstration effect", the decision must be carried up to the responsible executive in a centralized organization. Once the innovation is accepted, there the change is transmitted down through the hierarchy as instructions to the men

on the job. Each stage, moving up and down, requires adjustments in relation with other groups, both inside and outside the hierarchy. If the chain of communications breaks down, for whatever reason, it causes general frustration. Thus the construction of the city itself and the operation of its utilities and services will make a considerable difference in expediting the central decision-making and the rate at which new technology can be accepted and digested.

New technology enters by an infiltration process. The idea arrives most often first via foreign publications, generally through catalogs and journals. It is reinforced by discussion with experts able to comprehend its implications in a new application. The blueprints and specifications for production equipment, if any are needed, will come from abroad the first and second time the new technology is put to work, but thereafter a large share of this expertise is expected to be available close to home. Financing is negotiated by top executives, as is most of the hiring of new managers. The marketing strategy, advertising, accounting, payment of taxes, reporting of output levels, and the planning of future production rates are all undertaken at the headquarters site.

Modern technology is characterized by a low toleration for error. Most instrumentation is added to reduce the loss attributable to human error. In developing countries, where lack of experience makes human error more frequent, prevention is usually achieved through close, continuous, centralized control. Often the headquarters site is intimately involved in such operational control of production facilities, a responsibility superimposed upon the decision-making and design. Thus the headquarters district in a city needs excellent communications links with modern installations

elsewhere in the country and its service units should be endowed with quick response times when called upon for assistance.

The structure of the central city that propagates growth today hardly conforms to the recommendations of contemporary city planners. Certainly those cities that are most effective – Tokyo, Hong Kong, Sao Paulo, Osaka, San Juan – are never cited as examples to be imitated. However city planners, at least up to the present, have been seeking what may best be summed up as “serenity” rather than the capacity to accomplish a transformation. The kind of city that will be able to compete successfully in the future is one that generates wealth, therefore the planning will need to take a different tack.

The greatest challenge henceforth is presented by the construction of an urban core that promotes the rapid completion of a balanced set of transactions – economic, social, cultural, and political. Necessarily embracing the headquarters offices of manufacturing firms, retailing chains, banks, and transport services, it will also possess the securities exchanges, commodities markets, and insurance houses. National, regional, and city governments will be forced to maintain major bureaucratic establishments immediately adjacent or lose control over business. International firms will want a precinct of their own nearby, and the consulates of the main trading nations will choose to be on hand. The consulting professions – law, accounting, advertising, medicine, engineering – ordinarily fit into the odd nooks and crannies in this general vicinity. Somewhere in the heart of this complex a communications nexus must be founded that will link channels from the Comsat satellite to microwave relays, television, and the telephone exchanges. Intercity trans-

port must come into this core either underground, as in Manhattan, or high overhead, as in Tokyo. Hotels, department stores, and leading shops cluster as closely as they can to sites on top of the terminus, or along main channels carrying passengers away from it.

Any experienced traveler would feel immediately at home in such a central city. The urban ecology is exceedingly familiar. It represents the outcome of competitive forces that prevail in all metropolises and are modified somewhat only in the capitals of nations. Some things should be noticeably different in a resource-conserving future, however. Most striking, perhaps, is the earlier point that automobiles would be very scarce. Also, the spacious, residential suburbs reserved for top administrators and professionals would be replaced by more closely packed neighborhoods not far from work. This reduces the heavy investment in commuter lines. Similarly, the economy should extend to a parsimony of monuments and expensive landmarks equivalent to cathedrals. Conspicuous production needs to be avoided as much as conspicuous worship or conspicuous consumption, because the central city needs to be in flux, fitting land to new purposes when opportunities arise.

Cosmopolitan types of people, with their universities, libraries, cinemas, restaurants, coffee houses, and parks will accumulate in central cities. The gross densities of settlement are expected to be about 100,000 persons per square mile. This concentration can be very inconvenient if not comprehensively planned so that virtually all the space is available for human use at all times of the day and night. Thus areas given over to emergency reservoirs, waste treatment, water processing, and fish feeding may also become parks. The

most economical housing proposed thus far is a set of very light prefabricated units that can be stacked on top of each other, much as in the Habitat group in Montreal's Expo 67, but can be disassembled easily and put up elsewhere in another frame.¹⁴ (Although far from economical in Montreal, it remains promising in a tropical climate and in a city where water consumption is kept at an absolute minimum.) The face of the city – the structural form and the images on the structures – should be replaceable within a matter of months rather than years. The object is to conserve scarce materials and space, but otherwise remain relatively labor-intensive.

The greatest challenge of all is the programming of movements and some of the other activities so as to allow such a central city to operate almost continuously close to peak levels. The transition to a multiple shift society should extract enough extra use out of public facilities to reduce the capital costs per capita for urban infra-structure by at least half. Thus far the attempts to stagger shift changes and spread out peaks have failed, even in wartime when coercion could be used. The programming is expected to be feasible in the future only because huge amounts of routine data can be collected, processed, and digested by the enormous computing capacities expected to exist within a decade or two. If people don't know how to obtain desired services from the city they can take up short term instruction (equivalent in complexity to driver training for automobiles) in order to discover how to exploit the routines to their own advantage. Such a program maintains what amounts to a continuous census and an

up-to-the-minute map of all facilities tied closely into the central city; it would predict demand, and then schedule the movements of transport equipment according to pre-set criteria for optimization.

Approaches to optimization are likely to be undertaken in stages, sector by sector and level by level. The limitation is most likely to be imposed by the difficulties in the transfer of the social technology required to measure values and estimate behavior. Social technology includes the techniques of management science, attitude survey, motivational analysis, personnel testing and evaluation, accident prevention, community development, etc. The urban systems designer will have to utilize a good deal of it before he comes close to the optimum.

Conclusion

The key to the conservation of resources for the predominant share of the poor populations which are poorly endowed with resources lies in the control of consumption. The person engaged in technology transfer will find that many Western techniques already being adopted are much too wasteful. New findings reported in the past few years suggest that sub-systems for water, food, transport, housing, and central city organization can be proposed which promise to be far more economical in resource use than anything in existence today. The basic principle to be used in their design is to seek out means of substituting human resources for natural resources. This strategy puts much stronger emphasis upon the transfer of social technology and urban planning than has been evident until now.

NOTES

¹ The amount of land required to support a man at constant caloric intake has been declining at a rate of 1-2 % per year for the last two decades, and the amount of energy required to produce a standard amount of transport, cooking fuel, light, and home heat has been dropping almost as rapidly. Cf. H. H. Landsberg, L. L. Fischman, and J. L. Fisher, *Resources in America's Future* (Baltimore: Johns Hopkins, 1963). If a "One World" posture is accepted, as these authors do, the increasing efficiency argument should hold for some time to come.

² Latest reports in the newest *United Nations Demographic Yearbook* (1965) showed that 63 % of the countries in Asia, Africa, and Oceania registered a rise in natural population growth rate as compared to the baby boom year of 1948. Countries with large populations, such as India, Pakistan, Nigeria, Egypt, and probably China and Indonesia, fall into this category.

³ The most comprehensive current review of progress throughout the world at the moment is a monthly publication of The Population Council (230 Park Avenue, New York 10017) entitled *Studies in Family Planning*. Taiwan seems to have reversed around 1950, South Korea around 1965, and Hong Kong some time in between. In each of these territories a steady downturn in births is recorded every year.

⁴ See the entry under "Resources Planning" in the *Encyclopedia of the Social Sciences*, 1967.

⁵ Richard L. Meier, *Developmental Planning*, (New York: McGraw-Hill, 1965).

⁶ An estimated 49g. of coal equivalent energy per ruble of GNP as compared to 28g. for the United States in 1963. Source: *U. N. Demographic Yearbook* (1965). The difference is attributed to weather and the costs of overcoming vast distances.

⁷ Curiously enough, although the payout on investments in general education has been high, the return on vocational education as it has been organized to date seems to be very low. For a fine review of the theory and recent findings see M. J. Bowman, "The Human Investment Revolution in Economic Thought", *Sociology of Education* 39, Spring, 1966, pp. 111-137.

⁸ John F. C. Turner, "Uncontrolled Urban Settlement; Problems and Policies", Working Paper No. 11, United Nations Inter-regional Seminar on Development Policies and Planning in Relation to Urbanization, Pittsburgh, U. S. A., 1966.

⁹ I was impressed with the design of the Hydroponic Gardens of California installation in the city of Fremont using the Auto-Gro process. Publicity has been surprisingly small. Reports on experiments leading in this direction have been made by J. R. Seagrave, "Aquaculture", *Agriculture Pakistan* XVI, No. 3 1965, 257-72.

¹⁰ R. L. Meier, *Science and Economic Development*, 2nd Ed., (Cambridge: M. I. T. Press, 1966), pp. 58-74.

¹¹ Advertising is best suited to selling surplus commodities or processed foods with a relatively bland taste. Among the latter the most likely to be accepted are breads, baby foods, frozen custard, dehydrated soup, fine-grained sausages, *to-fu* (jellied bean curd), soy sauce, additives to curry, etc. The Japanese marketed two varieties of algae-based yogurt, using the *Chlorella* species popular in laboratory work as a key ingredient, during the year 1966.

¹² A review of recent thinking on megalopolitan transport was formulated as a total system for the United States Northeast Corridor. If applied to India most costs would increase, resulting in fares of 3-10 c/mile, by our estimate, which is tolerable only as a last resort. Massachusetts Institute of Technology. *Survey of Technology for High Speed Ground Transport*, prepared for the United States Department of Commerce, Contract C-85-65, Cambridge, Mass., June 15, 1965.

¹³ This is still an inadequate statement about a subject that is just beginning to be comprehended by investigators so that the work of sociologists and political scientists is beginning to merge. Cf. D. J. McCrone and C. F. Cnudde, "Toward a Communications Theory of Democratic Political Development: A Causal Model", *American Political Science Review* 56, March 1967, 72-79.

¹⁴ S. C. A. Paraskevopoulos et al., *Structural Potential of Foam Plastics for Housing in Underdeveloped Areas*, Architectural Research Laboratory, University of Michigan, Ann Arbor, Michigan, 2nd Ed., May 1966.