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9. ABSTRACT
The subjects considered in the course of the symposium and therefore in these volumes were construction, transportation, housing, water resources and nutrition--all highly relevant to concerns of the developing countries and all subjects of current interest at MIT. The four volumes of this report contain most of the papers that were commissioned to formulate questions and issues. Volume 2 contains the following papers by participants in the symposium:

Incremental Infrastructure, Richard Bender

Self-Help Infrastructure: Applications of Irregular, Small-Scale, Incremental Systems for Residential Utilities, Ian Donald Terner

Roads and Highway Transportation in Developing Countries, L. Odier

Urban Transportation Problems in Developing Countries: the Role of Technology, George W. Wilson

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PROCEEDINGS OF THE M.I.T. SYMPOSIUM ON STRATEGIES FOR A.I.D. PROGRAMS IN SELECTED AREAS OF SCIENCE AND TECHNOLOGY

J. P. Ruina (ed.)

VOLUME 2: HOUSING, TRANSPORTATION and WATER RESOURCES

April 1974

Massachusetts Institute of Technology
Cambridge, Massachusetts USA

CONTENTS OF THE SYMPOSIUM PROCEEDINGS

INCREMENTAL INFRASTRUCTURE

Presented at the M.I.T. Symposium on
Strategies for AID Programs in Selected
Areas of Science and Technology
April 23-26, 1974

Richard Bender
Professor of Architecture,
University of California

"The first phase of our industrialized age has been characterized by concentration and specialization of production, exploitation of resources, both natural and human, and a high degree of material progress. City and country became separated. Serving different ends, they came to be in opposition to each other. Will the second phase of our industrial age reverse these tendencies? Will that phase be marked by decentralization and diversification of production, both industrial and agricultural; by the integration of these two kinds of production and of the city with country? Will the city become more human? Will exploitation of resources be replaced by their planful use and careful preservation?

"These things could come to pass. . . . We cannot forsee the future. Yet we know that the realization of these human ideals will depend on the mind and will of man. And we may add, with assurance, that the very survival of civilization as we know it may depend on the degree to which man approaches this ideal."

Ludwig Hilberseimer
The Nature of Cities

ABSTRACT

Incremental construction is identified as a major tool in the attack on the world housing problem. This technique takes a variety of forms: self-help, mutual aid, and the work of small construction organizations. They use industrially produced tools and materials but are not centralized or industrialized methods. While three techniques have proven effective in the production of dwellings, their use has been restricted by the lack of parallel technologies for infrastructure: incremental service and support systems.

This paper sketches the background of this problem. It then locks at the forces behind recent technological developments, suggests alternate directions and strategies which can be used to achieve them. Centralized and linear forms are contrasted with others which are dispersed and incremental. Capital intensive and labor intensive technologies are explored and examples of water, waste-water, and energy systems are illustrated. The use of "Trickle-Down" and "Direct Action" are discussed as is the relationship between this problem as it appears in developing and developed economies.

. . . . .

This paper was prepared at the Architecture Experiment Laboratory, Department of Architecture, University of California, Berkeley. Bruce Cousins assisted in the research, Bernard Stein and Robin Chiang made the sketches, Joanna Taylor edited it, and Sue Arnold and Sylvia Russell prepared the manuscript.

The research was done in parallel with the NSF/RANN-supported study: "The Industrialization of the Building Site: An Evaluation of Experience in Operation Breakthrough."

Background

In September, 1972, President Salvador Allende addressed VIEXPO (Exposición International de la Vivienda) in Santiago, Chile. Dr. Allende described the housing situation in Latin America, which is typical of the situation in developing countries around the world.

In Latin America there is a shortage of about 20,000,000 dwellings; over 100,000,000 people are homeless. The housing which exists in Latin American nations is occupied to a density of 5.2 people per room; 3.2 people per bed. While 78 per cent of the populations of urban areas have drinking water supplied to their houses, the same is true of only 31 per cent of rural populations. Less than 5 per cent of the urban population of Latin America is served by a sewage system. Two hundred thousand children die of food and water related diseases each year.

In Chile itself, Dr. Allende said, there was a gross shortage of about 600,000 dwellings. (The shortage had been about 300,000 in 1940.) More than 35,000 dwellings per year are needed simply to keep up with population growth and new household formation while age, fire, and seismic shock destroy more than 15 per cent of the existing stock each year.

In Chile, as in developed and developing nations throughout the world, attempts to implement a massive housing program involving the rationalization and industrialization of building have failed. These programs have been expensive in their use of labor, specialized skills, equipment, capital, and administrative energy. Inevitably they have been inflationary, slow to materialize, and poor in terms of performance.

Hundreds of millions of people around the world, looking for a better life, now expect, and are demanding, a reshaping of the environment toward their needs, desires, and requirements.

An increasing number of those of us involved in building realize that our approach is at least partially responsible for our failure to meet these demands. Many of us blame the industrial process for the chaotic environment we live in, rather than placing the blame where it belongs: on men and institutions which have not learned to control it.

Throughout the world, "industrialization," "development," and "emergence," have come to mean a major population shift to urban areas. Added to general population increases at an accelerating rate, migration has exploded urban populations. But existing institutions have not been able to provide housing at anywhere near the rate of urban expansion. The problem exists in both the developed and undeveloped countries: urban population increases faster than urban services and institutions; housing production falls well behind need, and there is a general and substantial decrease in the quality of the urban environment.

The programs governments mount to increase housing production are merely repetitions of unsuccessful earlier efforts. They spend costly and scarce resources at the expense of that which is cheap and widely available: the energy of the people.

While the institutions we look to for help in this area are failing (formal, visible institutions such as "The Building Industry," "Developers," and "Government"), other, less visible efforts have shown some success. In developing nations, squatters, owner-builders, and a variety of ad hoc community organizations have succeeded in producing surprising numbers of houses. Over time, these houses have developed to amazing levels of maturity. They have grown to be slums of hope, not of despair. In more developed nations a similar but less spectacular success is found among urban homesteaders, self-helpers, and small builders. Throughout a generation of attempts to build a "Housing Industry," the scattered and unorganized small builder has shown great productivity while major government/industry programs have failed.

Today, in both developed and developing countries, the creation of dwellings is not a serious technical problem. New materials, tools, and concepts are in the hands of an energetic and determined population; houses do get built. But in almost every case this production is constrained, and the finished dwellings are threatened by an inability to match production with a decent level of urban infrastructure. All too often, these efforts take place in communities deprived of the most basic of urban services. While individuals and small groups are often able to make homes for themselves, they are unable to create urban systems: they have labor but no capital, they have access to resources but not to the means of production. They are surrounded by a technology which is outside their reach.

New arrivals at the urban fringe ("bridgeheaders" in developing countries, "suburbanites" in more developed countries) find a number of obstacles between themselves and adequate urban services.

The free forms of most of these communities will not accommodate the linear systems, gridirons, and rigid networks of most existing water and waste systems. The new communities tend to be on marginal land. They occupy the steep slopes, rocky outcrops, swamps, and seismic zones which earlier and more affluent settlers have bypassed. Most of the traditional utilities are constrained in these situations. Pipes are infiltrated by high water, repeatedly fractured by earthquakes, and are made impossibly expensive by the problems of setting in rock or on steep slopes. Also, in the case of squatter and most owner-initiated settlements, building patterns have solidified long before the capital to install water, sewers, drainage, or roadways becomes available. Therefore, installation of these systems means modifying the form to fit the needs of the technology—the destruction of some homes and of the texture of the community.

Many service systems designed for temperate climates prove unreliable in the extreme climates of developing nations. Systems designed for careful maintenance by trained engineers are equally unreliable; they break down unexpectedly, and the tools, parts, and technicians needed for repairs are not available.

Finally, the increments by which the conventional service systems are logically enlarged are too large to serve the new communities efficiently; yet there are no small-scale alternatives in the planner's repertoire. The homebuilders are helpless in the face of most of these large, rigid, inaccessible systems. As individuals and as a community, they find they have no power, no "clout," no effect. They are not important enough for the system to respond to them.

Are there alternatives to large, rigid systems?

Of course!

Some of them are products of a new and highly sophisticated technology. Others are variations of old familiar institutions: the well, the bucket, the oil can, bottled gas.

This paper will explore the problem of providing an appropriate level of support and service to new increments of urban housing. It will examine the dynamics of technological development and identify likely forms by which a new urban technology may express itself. Finally, it will identify some promising technologies and suggest public policies to aid in their implementation.

Directions in Urban Technology

Of all the areas of building technology, the most established, the most heavily capitalized, and the least responsive to changing needs of the community are those used to provide site services and utilities. To receive these services, a community must adapt itself to the requirements of the technology. Straight streets, regular slopes, widths to accommodate construction maintenance and service vehicles, easements for access, all characterize the developed (i.e., serviced by modern utilities) area.

All too often the nature of these services means the end of community life: "We cannot serve that area" or "We will have to bulldoze those houses to provide access for our lines" or "Extending our lines to thirty more units will cost as much as the whole system."

Thus, a major goal of any new technology should be the provision of systems which can respond to growth. Can we bring water and waste systems to the house in the same, incremental way that we can add houses themselves? Are these systems which anticipate growth? Systems which respond to growth? If so, what will their nature be? How will they be developed, introduced, owned, paid for, maintained, and operated?

This paper will address these questions, attempt to identify alternative technological approaches and assess their implications for a range of community forms. Before examining the specific technological approaches, it may be valuable to examine the recent development of technology and to point out the lines along which we can expect new development to take place.

Ephemeralization

There are a number of clear trends in the development of building technology. One of the clearest of these seems to be a definite movement in new products and processes, in institutional and organizational structure, and even in building, toward ephemeral structures. Buckminster Fuller has called the phenomenon "ephemeralization."

There are many examples of ephemeralization, and structural examples are easiest to find. The fact is that structures are becoming lighter and lighter. Compare Stonehenge with an Egyptian or Greek column, trace the development on through to moulded iron and rolled steel sections, or consider some of the more recent trussed and tensegrity structures. In some recent air-supported structures we find ourselves walking through an invisible column of air. A whole class of structures does more with less. Structures have become lighter as their material becomes stronger, assemblies optimal, and organization more sophisticated. One can find similar patterns in horsepower per pound in engines, the weight of fuel required to heat a house, or the weight of the equipment it takes to communicate, in radio, TV, or computers. As technology improves, its hardware becomes lighter. Every technology displays examples of this kind. Our survey of the changes in methods and materials shows the building industry is no exception.

Clocks and Clouds

A second important phenomenon involves "software" as well as "hardware," and runs through an entire group of tools and organizations involved in the change in building. There is a change to be seen in the structure of many of the things around us, from a linear-mechanical structure to one of dispersion. The physicist Carl Popper has described this as a change from "clocks to clouds." It is a shift in view which is basic to an understanding of the new forms the building industry may take.

We generally understand that a clock is a machine. It is hard, precise, and predictable. One knows exactly where each part will be, how it will operate, and what it will be doing for the period of its operation. Our image of most mechanisms tends to be like this—clocklike.

There is another common mechanism, however, effective, but less easy to visualize. Its actions are more difficult to predict. A cloud is such a mechanism: a cloud in the sky, a cloud of electrons, molecules, gnats, or smoke. A school of minnows can be considered as a cloud, as can many of the institutions of our society. And as we learn more about a cloud of minnows, we find we can make many of the same predictions we can about the clock. The cloud also moves according to certain rules: its motion is related to temperature, sunlight, food supply, sea current, season of the year, and a host of other things. The factors are complex and the rules are not always clear.

For instance, any fish at any time can swim into or away from the group. But the mechanism, though invisible, is real, and it controls the operation of the cloud. At some point, when the minnow finds it is a certain distance from the center of the group, it feels threatened or frightened. For some strong reason it returns to the group and moves as a part of its pattern. There is an invisible control system. The cloud is a mechanism with a more complex nature than a clock, but a mechanism nevertheless.

Let us see how this is related to the changing structure of the building industry. In many of our approaches to industrialized building, we have assumed that we are dealing with clocklike mechanisms at the very time that these mechanisms are becoming more cloudlike. There are two interesting manifestations which illustrate this, one in business and the other in politics.

The modern corporation is a clocklike mechanism. It has a clear purpose, direction, and point of view: the Coca-Cola Company makes soda; U.S. Steel makes steel. The structure of the corporation, its leadership, goals, and techniques have traditionally been clear: they resemble clocklike mechanisms. Yet the corporation has been restructuring itself for some time. In the process, it has become the conglomerate, and this represents a steady shift from a clocklike to a cloudlike mechanism. What does Litton Industries do? What business are they in? What tools do they use? What do they make? What are their goals? Who is the leader of Litton Industries? The leaders of the 19th century corporate industry were well-known figures, but the president of the giant modern corporation cannot cash a check at the supermarket without identification any more than you or I. The control system as well as leadership, tools, and goals has become much more cloudlike, and more difficult to perceive.

Politics offers another interesting parallel. Compare the rigid structure of the Communist cell as a nineteenth century political organization with today's amorphous "Movement." People might ask the same questions of the Movement they might ask of Litton Industries. Who is the leader? What do they want? What do they do? What are their goals? The Movement's goals go off in many different directions, and its direction is the result of many, apparently conflicting, activities. In short, it is cloudlike.

Cloudlike mechanisms are developing all around us, in education, medicine, government, transportation, recreation, and even housing. One of the things we might look for in our search for a new conceptual framework for urban technology is a shift from clocklike images to cloudlike ones. What would a cloudlike municipal water system look like?

The Escalation of Technology

Another of the trends we should look at might be called "the escalation of technology." As a technology develops, it follows a series of cycles in which each new invention solves an existing problem but creates a new problem. The new problem is on a higher level of complexity and requires a solution involving a higher technology. This poses a still larger problem which has to be solved at a still higher technology. Invention becomes the mother of necessity.

As this proceeds, escalation becomes hypnotic—eventually, solutions are seen only in terms of the technology that caused the problem. If schools are bad, we spend more money on them. If the welfare system does not work, fund a new program. If the bombing is unsuccessful, drop more bombs.

In building there are any number of examples: for instance, the computer.

With the computer problems can be solved that could not have been considered before. However, the use of the computer demands increasing complexity in the data required (one needs data to acquire data). So we limit the richness of our measurements to fit the computer, and again we find that while some problems are solved, larger problems are created.

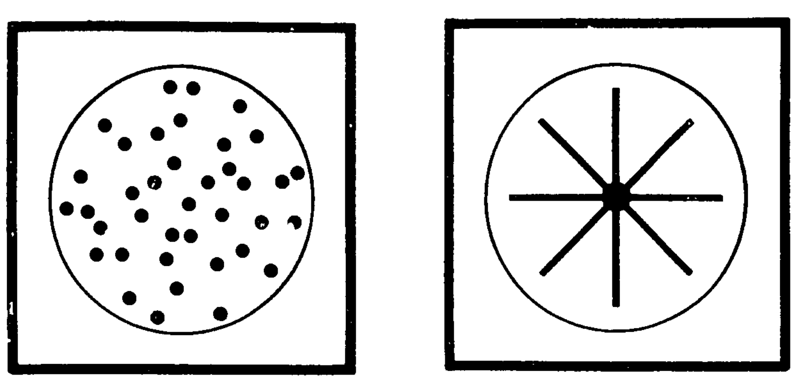
One of our best examples of technological spiral is seen in the development of the automobile. The original invention met a need. Therefore, a commitment was made to street construction and paving. Paved streets made cars more useful. More cars were made. Soon many people had cars, and the streets became crowded with them. Planners began their work; they reshaped the street patterns to carry the increased traffic. Wide streets, boulevards, and avenues were built. The number of cars again increased. Streets became slow, clogged, and unsafe. Freeways were invented. They cut through the city, and opened its structure. Traffic moved again. People spread out. However, the city, even in its new amorphous form, began to clog. Today the air is bad, filled with noise and smog and smells: witness the spectacle of Los Angeles. We call for a return to public transit but it is too late. In the city's new form transit lines cannot reach enough people to pay for themselves. The city is now too dispersed for anything but an automobile solution.

The epitome of technological escalation is "urban technology" itself. For it is the technology of cities (water, waste, communications, transport and other similar systems) which make urban concentrations possible. At the same time, urban concentrations are continual sources of new problems: shortages of water, pollution of streams, poor communication, and congested transportation. The answer to each is seen in improved technology of the same kind: new reservoirs and aquaducts, new techniques of treatment, more lines, more roads. In each case, the city sees solutions in terms of the very technology which makes the problem.

Cycles of Technology

As technology escalates, another interesting phenomenon can be observed. It moves through a series of alternating cycles from a dispersed to a specialized to a dispersed form once again.

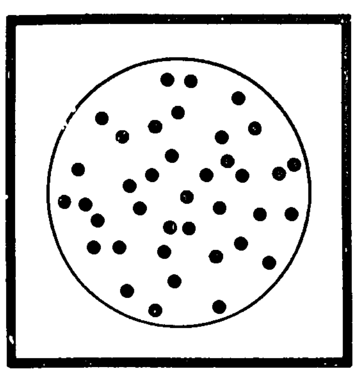
Communications offer a good example. In a small village, everyone is able to beat a tom-tom, and anyone in the community can hear it. One does not need any special equipment or need to be hooked up to any system. If you can hear the signals, you get the message. But you can hear it only in the village. In the nineteenth century, with the invention of the telephone and telegraph, we took a jump. One could speak from any part of the world and be heard instantly, by anyone who was on the line. But note that a trade-off was made —between a small-scale operation, dispersed and free, and a large-scale operation which was linear and specialized.



Dispersed **Linear**

Western civilization is in the mdist of that kind of specialization today. We have traded off the house that we made by ourselves, or with members of our community, for a house with many things that we have never had before. We have given up control of our environment for dishwashers, washing machines, and color television. Today our houses are made on a take-it-or-leave-it basis. Manufacture is linear, specialized, and most often remote. We can find we must take the entire system in order to enjoy a part of it. Laws reinforce this system. Most towns will not allow self-made houses, utilities will not serve them, neither will insurance companies. We are all on the line.

If we pursue this theme, and look at communications again, from the tom-tom to telephone to radio, television, and eventually television interconnected with satellites, tape, cassettes and computers, we find an interesting result. If we go far enough in this direction, we eventually emerge at the other end of the tunnel to find a new dispersed state. We move from the wire to the wireless, the track to the trackless, and we no longer have to be on the line. A small piece of equipment on either end is all that is needed for the whole world to communicate.



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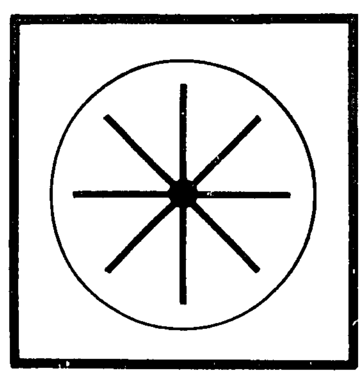
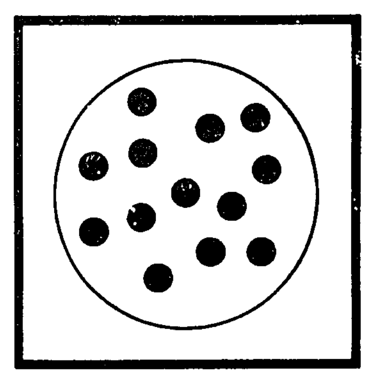


Linear



Dispersed

This is the "Global Village." What once took place on the scale of a village takes place now on an international scale.

If we look at building technology in the specialized-to-dispersed framework, we see that at this time we have made the first jump in the cycle and that we are on the verge of the mastery of techniques which will allow a new level of freedom.

We are moving house building from the site into the factory, but this is transitional, not an end. If we go far enough, we may finally emerge with a system in which technology begins to serve the individual instead of causing him to come to the factory to be served. This would be cloudlike, rather than clocklike, technology.

The "Global Village" analogy shows how we spiral from dispersed to linear to dispersed technologies of a new scale. There is an important parallel to this, involving institutions, rather than hardware. If we look at radio as it was a generation ago, we find that a few companies were making most of the equipment needed to broadcast and receive. The same few companies also controlled the radio networks. And the same organization which made it possible to use the radio controlled what the radio could say. Television takes the same form today.

It is important to understand that as technology moves from the linear to the dispersed form, as it improves past the first breakthroughs, technical developments occur which make it possible to disperse. At the same time control is removed from a few people and spread to many. As radios became cheaper and easier to make, and as the whole technology of radio broadcasting was better understood, radio was assimilated into our lives. New techniques made the radio station easier and cheaper to run, and less provincial, although more dispersed. The network changed from a clocklike to a cloudlike structure. There is hardly a town today that does not have several radio stations. Larger cities have many, and unlike a generation ago, when the few networks all had similar programs, they represent a wide diversity of interests and opinions.

Television today still has a small number of choices, in fact, choices are not really choices at all, but the technologies and institutions which will change this are already visible. On radio we hear talk, news, classical, rock, and country and western music; programs are devoted to weather, business, and farmer's reports, as well as focused on local and national issues. We can expect, as television matures, that the same kind of a change will occur; television will become dispersed, like radio. Cable television will restructure the industry, but real change is more likely to come out of a new, more dispersed technology—perhaps video tape cassettes. The idea that programs do not have to be listened to "on the line" or at a particular time or in a particular order or place will revolutionize the medium.

To carry this analogy a little further, the change in the technology which makes music available through radio, records, and tapes has done more than simply broadcast the new sounds. It has meant a much wider influence by "out-groups," by the young, by the representatives of cultures which are not part of the Establishment. Innovation comes more easily, change comes more rapidly, because music is no longer tied to established structures which shape and control the medium. Technology has moved to a point where entry into the music system is cheap and easy, and control of the tools is in the hands of many people. There has been a dispersion. A cloudlike atmosphere has replaced the clocklike mode which is still common in televison.

Discontinuity

The last item on this list involves the idea of discontinuity. It is the most disturbing thread which runs through the material we have collected. It is disturbing because it tells us that while we plan for a future based on the continuation or acceleration of present trends, the futur^ promises abrupt discontinuity. We really must invent a new conceptual framework. We agree that things are changing, but we can only anticipate changes which are linear. We cannot picture a world in which things have radically changed, where there are sharp breaks or jumps—or discontinuities—between present and future.

Yet change is often discontinuous. In the development of science and technology in the thousand years before the late eighteenth and early nineteenth century, there were many inventions which were absorbed into the dispersed, medieval structure of the world. Only toward the end of the nineteenth century did a whole series of organizations form out of a changed view of the world. They came as part of a discontinuous jump; corporations, big cities, public utilities, and most universities were formed at that time. The bathroom, the city water system, fire and police departments, public education, and medical treatment as we understand it, all emerged from developments in the physical sciences which had taken place in the centuries before. Since then, we have been in a relatively steady state. There have been few changes in our conceptual framework. But the last hundred years have seen great inventions and developments outside the physical sciences, in the social, medical, and biological areas. We have yet to see the institutional changes which will grow out of these developments, the new institutions which will affect our lives, as the building of the railroads, the steel factories, and the incorporation of the cities shaped our lives in the last century.

These are some of the trends we must begin to contemplate if we are to assemble a picture of a future building industry. They are some of the elements which our new conceptual framework must support. They are elements of an industry which will be more cloudlike just as the elements of our earlier conceptual framework made inevitable the building of the corporations and factories in clocklike form.

Looking at Systems

An urban hardware system is a collection of manmade objects which are related to each other in some dependent way and which have the property of collectively serving some function complete in itself. There are inherent difficulties in examining urban systems. They can be described at many levels of magnitude and complexity. Thus, the fixtures, water pipes, and drainage lines in a house together describe its plumbing system, but this system is linked with others to be, collectively, the community's water distribution and sewage disposal system. At the community level, objects like reservoirs, pumping stations, sewage treatment plants, and the manpower needed to operate and maintain them become part of a larger system. At the regional level, river basins, dams, and pollution control need to be considered in a like manner. The difficulty is increased when we realize that all of these objects are really only one possible solution to the provision of water for drinking and the disposal of human waste. We have become so accustomed to some of our ways of dealing with our functional needs (plumbing systems for water supply and human waste disposal) that we find it difficult to separate our ideas about fundamental performance requirements from the existing solutions to these requirements.

There now exist other solutions to water supply and waste disposal needs. For example, the water supply and waste disposal methods of primitive societies are still capable of being considered for use, even though the components are simple: a well, a stream, a bucket, and a trench in the woods. These objects serve the same functional purpose. In terms of quality, they may be better than the high-volume plumbing systems needed to serve urban areas. At the other end of this spectrum is the water supply and waste disposal system of the Apollo space capsule designed to take three men to the moon: a completely closed system in which water can be recycled to the humans occupying the capsule.

Each of these systems is based on a different technological capability, and each has associated with it a completely different scale of personal and social costs. The point is that there are different systems solutions to these fundamental functions of man, and there exists the possibility of many other solutions if we wish to address ourselves to the opportunity.

The following sections of this paper attempt to provide a framework for the evaluation of these alternatives.

Urban Services

Urban serv ices can be examined from many points of view. One convenient classification groups service systems on the basis of location. Thus, we recognize on-site systems and central or collective systems. Combined systems—combinations of a large-scale, central system and a smaller on-site system—form a third category.

On-site services are generally owned, operated, and maintained by the owner of the property. He has exclusive use of them as well as control of and responsibility for them. For example, water for a rural site can be drawn from a well on the property; waste water is returned to the earth via a septic tank. In the same situation, gas or electricity can be provided by a larger utility company or gas in containers can power a generator and wood can be burned for heat.

This example portrays a small-scale system, but on-site operations can also provide services to larger, institutional sites. Sewage treatment, incineration, central heating plants, and total energy systems are examples.

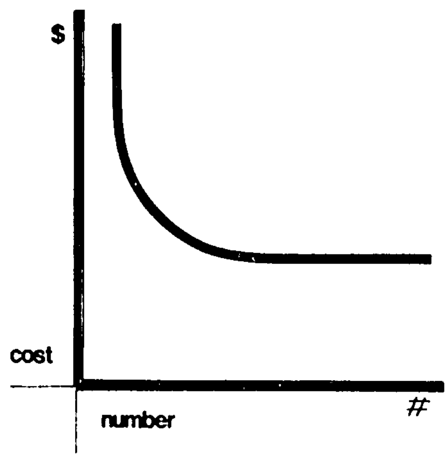
Collective services are generally characterized by lines and networks. These site services are large, expensive, and are used at all the levels of the urban hierarchy beyond the dwelling. They can serve a great many units from the same central system of treating, processing, delivery, and removal. In a typical collective system, canals, aquaducts, mains, and pipelines carry raw water to be treated. Treatment facilities filter, aerate, and chlorinate the water for domestic use. A distribution network then conveys the water to each site. Waste water is collected by a similar pipe network. This network transports liquid waste to plants where it is treated and released to the environment. Collective transportation and treatment requires a high degree of social and technical organization. It also requires a tremendous initial capital investment. However, at the right scale and with sympathetic community, topographic, and soils conditions, the network approach is very inexpensive overall, and it provides a high degree of utility for its users.

Combined systems are also common. These involve the interdependent use of both on-site and collective systems. One can have his own well on the site and be tied to a collective waste water network. Electric power can be drawn from municipal lines while water is heated with solar energy. In systems of this sort, the on-site energy system serves the basic demand while a conventional water heater is operated by gas or electricity to meet peak demand. This approach to the delivery and treatment of site services allows some independence from the large-scale network. It uses small increments of service technology to avoid the intensive capital outlay required for the next, larger, increment of the collective system.

There are many reasons why a correct choice among these approaches is crucial to a community. On the one hand, the systems offer the improvement of domestic health, sanitation, and livability and provide a basic impetus for upward social and economic mobility of the individual. In the aggregate this results in a benefit for the whole community. On the other hand, if a community decides to spend its resources on expensive underground networks and a collective purification plant, the effects on the community's capital resources can be devastating. This is a wrong decision, for finally, the establishment of the collective large-scale network is a capital investment that, for better or worse, fixes the urban fabric of the community. Once committed to, these systems make it a difficult or impossible task to change the land-use patterns in response to changing economic and social needs. These important aspects of community development must rank high in the decision-maker's mind when decisions about the type, location, performance, and costs of site services are considered.

Too often, the decision is made without full knowledge of alternatives, or with mistaken ideas of the true costs of these alternatives. For example, it is a common argument that only with large-scale development can we achieve the economies of scale that will lower costs and bring services to a larger consumer group.

The curve below is a familiar diagram of this idea. The unit cost drops as the number of users increases.

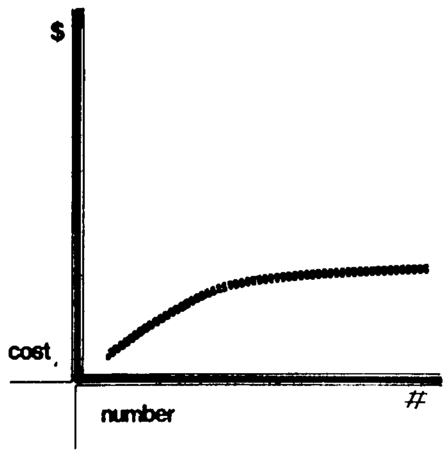


Large System

Obviously, this is often true.

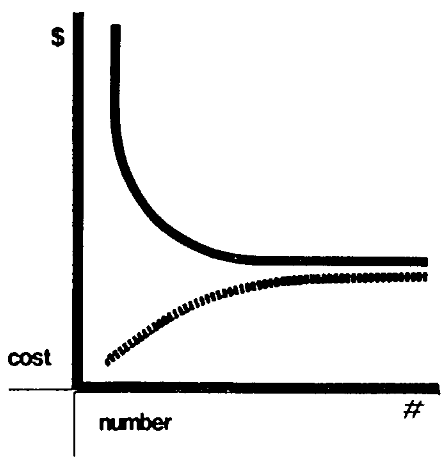
Large-scale operation often does bring costs down. Elimination of redundancy, bulk buying, and the resources for careful planning are familiar economies of scale. The high quality and low cost of many manufactured products speak to this.

But there are many situations in which small-scale solutions are more economical than large. In fact, the first curve makes sense only if you are committed to a large-scale system. Large water systems can buy pipe and chlorine at a lower unit price than small ones, but many on-site systems completely eliminate the need for both of these. Because it starts at the other end of the scale, a cost-per-unit curve based on simple on-site technology might look like this. The unit cost increases as the number of units increases.



Small System

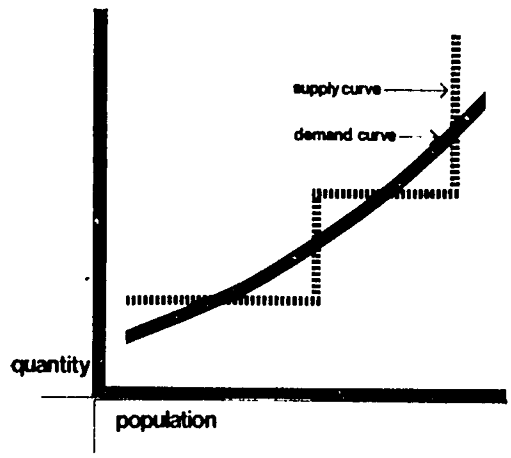
So small-scale systems form a quite different picture. And where the technology is in tune with a particular situation, small-scale systems provide an important alternative. Look at the two choices.



Comparsion: Large vs. Small System

They represent more than a "systems" or financial decision. For, in fact, it takes quite different means to operate them. The large-scale system can be planned only by experts; specialists. It takes a major community commitment to set aside the necessary land, to finance and build it, and to maintain it. But small-scale systems are in the hands of individuals or small groups. A single family can decide to install it. They can build or buy it without the cooperation of their neighbors or local authorities. They can serve themselves in situations where the central system cannot or will not serve them.

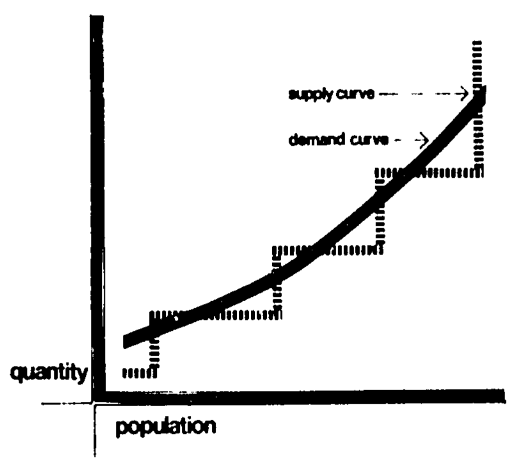
The curve below illustrates the typical situation, in relation to growth of large systems.



Large System

As demand rises beyond the capacity of a given increment of the large system, performance declines. The quantity available to each user drops, or the community must increase capacity. As the curve indicates, however, the next increment is a large one: its capital cost is high; its capacity will not be needed for some time; the new construction will involve high cost, mess, disruption of service, and changes in the community structure. In many cases the community resists it. The solution seems to be to suspend growth rather than to increase service. Communities from metropolitan Washington to the San Francisco Bay Area have recently taken this approach. In developing countries this is a regular response by authorities to the arrival of squatters and owner-builders.

In those cases where technically viable incremental units of urban service are available, the response to the demand curve can look like this.

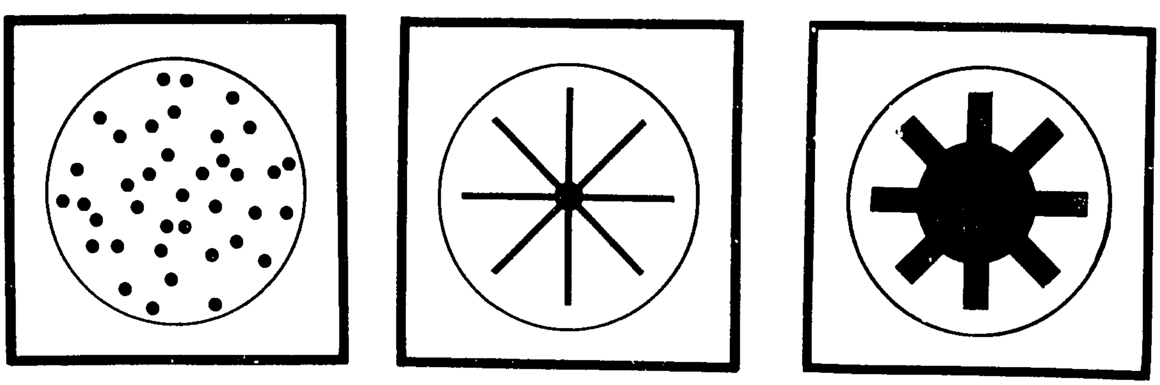


Incremental System

In this case, good prediction is much less important, for front-end capital needs are reduced and it is possible for individuals and small groups to respond to their own needs. While it is clear that the technology for this kind of response is important to the squatter in a developing country, it is more surprising to note that these technologies may be basic to development in more mature situations. The landowner along a protected lake might build if he could demonstrate the ability to treat his waste with no impact on the adjoining water. The tract builder in Montgomery or Marin County might be permitted to add a cluster of 100 units if he could provide high quality service without drawing on already overloaded service systems.

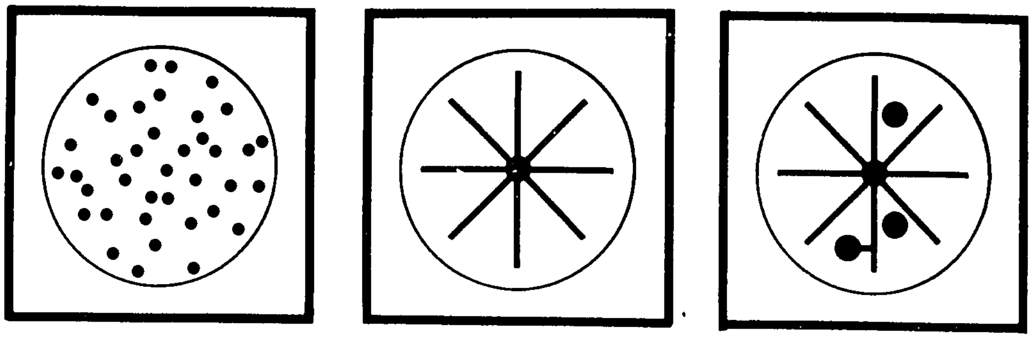
Again, small-scale (on-site) technologies and large-scale (collective) services can support each other. Such mutual support can take three forms. In one, the incremental technology serves the new population until the sum of these new additions can support the expansion of the collective system. Then, where the collective system offers the desired performance, the individual units are replaced by a central system. In the second, the incremental installation remains and each unit is equipped with both systems. One system backs the other up in emergencies, or takes the load at peak intervals, and thus the individual installations reduce the size of the required central system. Finally, with the appropriate technology, each increment can provide its own service at the highest levels of performance. In this case, the community is freed of the constraints of lines and networks, and it can return to the dispersed mode at a high level of sophistication.

To illustrate, we can continue the progressions we introduced earlier. Thus the central system route moves from dispersal to a linear centralized system and then on to a larger, more rigid and centralized linear system.



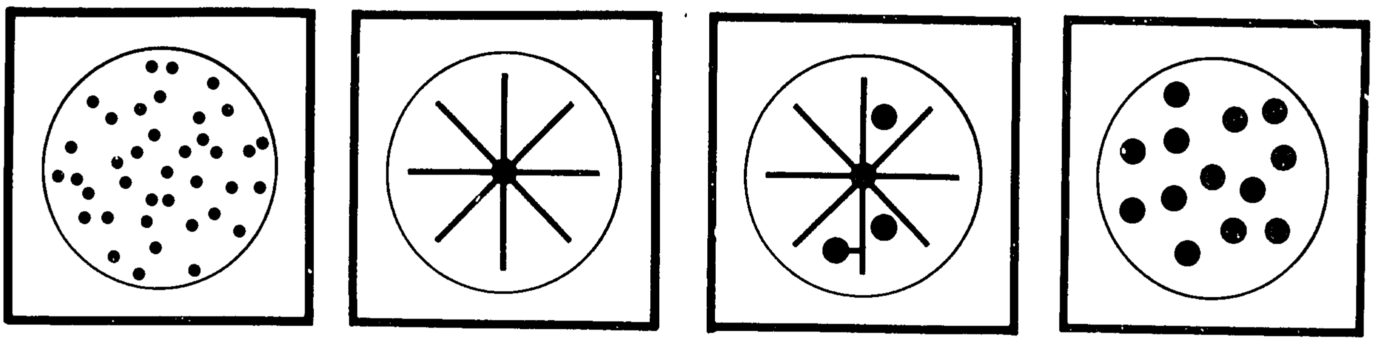
Dispersed **Linear** **Linear**

The combined route develops from the random-dispersed to a linear system which is later supplemented by a number of small increments.



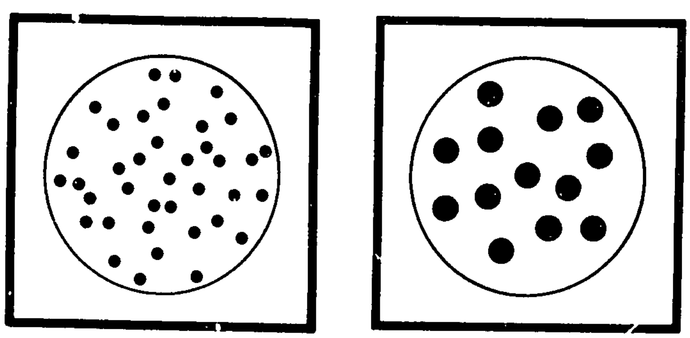
Dispersed .Linear Incremental

Eventually, as enough increments of the new technology are added, the central system may atrophy, and a new dispersed system capable of new levels of performance emerges.



Dispersed Linear Incremental Dispersed

In fact, with the development of these new compact incremental technologies, a fourth route may be emerging. As the technology develops, village systems can be replaced directly by new, urban-scale, dispersed technologies. For the owner-built communities of developing countries the implications of this change are enormous.



Dispersed Dispersed

For, as the density of a community increases, the performance of village technologies declines; wells go dry; waste disposal contaminates the water. Normally this calls for the installation of a central system, but alternatives to a collective system now exist. Aerospace technology ("black box" systems to purify and recirculate water) provides one set of answers. And more effective versions of traditional systems provide other models: the answer may be simply carts similar to those used at marinas and houseboat communities, to deliver water and to empty holding tanks.

Thus, many means to accomplish incremental additions to urban services exist. Our problem is to understand them, clarify alternatives and form strategies for development and implementation.

To help with this, we have attempted to array in a matrix form some existing technologies of urban services. Here we can look at these services as they increase in complexity, or simply in technical sophistication, and watch what happens as urban scale increases. Bearing in mind the previous discussion of technological cycles, this matrix enables one to compare alternatives and select solutions for a specific problem.

Water, waste water, and energy systems will be the focus of this discussion. While these technologies have been selected to reflect the needs of the residents of quatter settlements, they also represent significant opportunities for more developed communities.

Scale of Development / Level of Technology Matrix

SCALE \ TECHNOLOGY	Dispersed	Linear	Dispersed: capital intensive	Dispersed: labor intensive
House	PAIL OR BUCKET CARRIED FROM A STREAM	FIXTURES PIPES	REFRIGERATOR-SIZED "BLACK BOX" WATER-WASTE SYSTEM	TRUCK DELIVERY OF BOTTLED WATER TO INDI-VIDUAL HOUSES
Cluster	WELL CISTERN	LATERALS MAINS	ROOM-SIZED "BLACK BOXES" WATER-WASTE SYSTEM WATER-ENERGY SYSTEM	TRUCK DELIVERY OF WATER TO COMMUNITY TANKS
Neighborhood	PUBLIC FOUNTAIN	PUMPING STATION	MIUS WATER-WASTE-ENERGY SYSTEM	COMMUNITY WELLS CISTERNS

SERVICE **Water**

Scale of Development / Level of Technology Matrix

TECHNOLOGY / SCALE	Dispersed	Linear	Dispersed	
			capital intensive	labor intensive
House	PRIVY	TOILETS DRAINS PIPES	REFRIGERATOR-SIZED "BLACK BOX" WATER-WASTE SYSTEM FLASH INCINERATION	COMPOST TRUCK OR CART REMOVAL OF HOUSEHOLD WASTE
Cluster	COMMON TOILETS SEPTIC TANK	LATERALS MAINS	ROOM-SIZED "BLACK BOX" WASTE-WATER SYSTEM WASTE-ENERGY SYSTEM	TANK-TRUCK REMOVAL FROM HOLDING TANKS REUSE AS FERTI-LIZER
Neighborhood	COMMUNITY WASTE PICK UP BY CART DISPOSAL AS "NIGHT SOIL"	PUMPING STATION PRIMARY TREATMENT	MIUS WATER-WASTE ENERGY SYSTEM	METHANE GENERA-TION AGAL PONDS

SERVICE **Waste**

Scale of Development / Level of Technology Matrix

TECHNOLOGY / SCALE	Dispersed	Linear	Dispersed	
			capital intensive	labor intensive
House	COLLECTION OF WOOD PEAT COAL BY INDIVIDUALS	ELECTRIC OUTLETS GAS-OIL BURNERS WIRES PIPES	FUEL CELL SOLAR ELECTRIC GENERATOR	SOLAR COLLECTOR PROPANE GAS TANKS OIL TANKS
Cluster	CART DELIVERY OF WOOD PEAT COAL OIL COMMUNITY STORAGE	PIPE AND WIRE NETWORKS CENTRAL HOT WATER CENTRAL HEATING	"BLACK BOX" WASTE ENERGY SYSTEM TOTAL ENERGY SYSTEM	COMMUNITY SCALE SOLAR COLLECTOR PROPANE DELIVERY TO COMMUNITY TANKS
Neighborhood	WATER WHEEL WINDMILLS	GAS AND ELECTRIC SUBSTATIONS PROJECT POWER PLANTS	MIUS WATER-WASTE ENERGY SYSTEM	METHANE GENERATION FROM WASTE WINDMILLS WATER WHEELS

SERVICE **Energy**

Technologies

In these sample matrices, technology and urban organization are arrayed in ascending order. In each cell, a typical technology is noted. The following section will look at some of these cells, illustrating and pointing out alternatives for the transition from low to high technology.

We can begin with the water matrix. At the lower range of technology the clay pot and the bucket have traditionally been the means by which preindustrial, dispersed societies transfer water from its source to the house. The containers are manufactured in the family or by a specialist living nearby. Bark, skins, and clay were the earliest materials used in their construction. More recently, glass bottles, plastic containers, and metal cans have appeared. The use of these containers is limited by their size, the weight of water, terrain, and the distance between the house and the source of water. The user must go to the sources as often as household demands require. This can be several times a day or only a few times a week. Different societies have modified the bucket. It is carried on the head or two are carried on poles across the shoulders. They can be placed on or built into carts or wagons to increase capacity and they can be used to fill small storage containers in the house. In its various forms, the bucket is a quite adequate technology for a dispersed, labor intensive society.

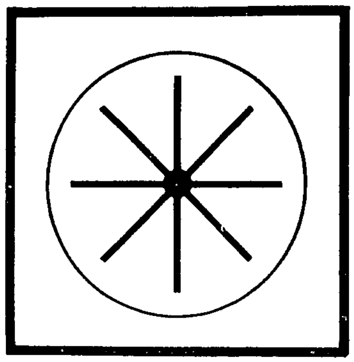
This means of water supply is slow, and physically demanding, but some important advantages are to be had. It is cheap, flexible, and when needed, readily available. For the users, face-to-face contact and social interaction is greatly facilitated. The trip to the well or stream is a time for gossip and communication. Water collection is expanded beyond a purely utilitarian function.

As people began to value their time for more productive purposes, and as new activities began to expand the quantity of water they consumed, societies sought time and labor-saving technology to replace the trip to the well. New techniques were invented to use time and energy more efficiently. Other new techniques stored and purified the water. Capital began to replace labor. Aqueducts that once brought water only to the central wells were expanded to bring water through piping networks to and then throughout each dwelling. The transition from the bucket to the distribution network involved the creation of permanent, linear, hardware systems. Concurrently, water districts, companies, regulations, and planning became part of the urban fabric. These systems are characterized in the second column of the water matrix.

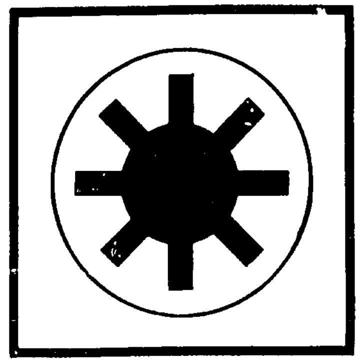
Optimization, economy, and efficiency were at the heart of this technology. But along with it came more than just a new, enlarged, and efficient water distribution system. Old institutions were disregarded; new institutions sprang up. One did not have to leave the house for water. The public fountain and groups washing clothes at the river bank gave way to storage tanks and pipe networks. Now water could be centrally collected, purified, and stored. Large volumes of pressurized water could be counted on. The benefits of this new engineering were obvious. The use of water increased; its quality improved. So did public health and productivity. As a result the systems expanded. Urban form was adjusted to their convenience. Today systems of this sort define a city. A heavy capital expenditure is necessary to build and support them, long planning and construction periods and a broad community commitment are needed to expand them. They provide a high level of performance at the expense of independence and flexibility.

A side effect of the large-scale linear system is continual growth; the escalation of technology. As water transfer and treatment become industrialized, demand must be generated in order to use capital and resources efficiently. Because networks of pipes cannot be enlarged conveniently or cheaply with each spurt of growth, tools to predict growth are necessary. Uncertainty, imperfect knowledge, and the large increments of construction needed to realize economies result in the construction of oversize pipes and facilities. As the population grows beyond the system capacity, supply is strained. This means a large initial capital investment. In many cases this investment must be made before the target population is reached. Investment of this magnitude must be paid for through use. System usage is the result of growth. Thus the growth cycle creates more development and an upward spiral of land value. This in turn encourages new development to seek cheaper land, spurring development, the next ring of low-density urban sprawl and the next extension of the system.

Growth, then, encourages each succeeding level of technology to become not only larger but more complex. The complexity is, however, not the result of diversity. The cycle of more demand is responded to by building a larger and larger system. More land is acquired for larger watersheds, which collect the water for larger storage reservoirs. Longer aqueducts and canals are necessary to transport the water from the reservoirs. Closer to the user, more pumping stations, demand balancing, and reserve reservoirs are required for maintenance of pressure. These in turn require more personnel to service, operate, and maintain the system. The system becomes a dinosaur. In most urban communities, they are so much a part of our life that improvements in water supply are seen only in terms of improvements in the system. From one linear system to a larger, more rigid one:



Linear



Linear

Efficiency and economies of scale reach a point of diminishing return.

As we can see, the other site services represented on the matrices demonstrate a similar spiral of growth. Waste water management has the same problems of networks and buried pipe. In addition, it has the other, more critical, problems of septic conditions and of human and industrial waste. The new large concentrations of waste cannot be absorbed by the natural environment. The economy-efficiency reasoning that has created the linear system fails to use the natural absorptive capacity of the land, it is a specialized system divorced from the land, and as a result it is involved with transporting waste over large distances, collecting, treating, and discharging it in large quantities.

If we examine the waste water matrix we see that the sewage system also began in a dispersed pattern, using the natural dilution capabilities of the soil. The individual homeowner and his family could simply dig a hole in a location that would not pollute the ground water of his well. Generally, it was at a short distance from the dwelling; often in a shelter of its own. Such a privy requires maintenance. It must be moved often. The user may have to brave the elements to reach his destination. As the population density increases, the land can no longer handle the quantity of waste produced. The inconvenience, the odor, and problems of health and sanitation push towards a higher performance solution.

In societies where land is at a premium, where land is used intensively, waste cannot be deposited in the ground at the house site, other systems have been developed. In the first stage of this development, waste is collected from each privy and carried away. In the most simple systems buckets are used. More commonly, carts, wagons, or tanks are used. Often the waste is sold to the farmer. Most large U.S. cities used techniques of this sort to dispose of human waste as recently as the early twentieth century. This "night soil" represented an extremely efficient way to dispose of a waste product.

The growth of waste water transport and treatment is in parallel with the development of central water supply systems. In these systems, the additional water provided by the new central water supply system must eventually be transported away from the house, treated and returned to the environment. Thus the reciprocal effects of growth stimulate yet another large capital investment. Increasingly large investments are called for in the collection, transport, and treatment of water and waste.

The waste water system becomes a shadow image of the water supply system. The linear network of pipes for both results in the familiar gridiron pattern, broad streets, and gentle slopes of modern cities. Collection networks are dependent on the grade requirements of gravity flow. In large systems, these result in trenching to great depths. Often the flow must be assisted with lift stations. Pumps must be installed and the stations designed to minimize the noise and air pollution they bring. Concrete, corrugated metal pipe, cast iron, and vitrified clay pipe are the materials used to manufacture the pipe to transport raw waste. Skilled specialists with special tools are needed to install them.

While the scale increases in waste water treatment do not demand the great land holdings that the water supply system does, the concentration of pollutants released to the environment does require an equivalent amount of other valuable resources; energy, equipment, buildings, skilled managers, and specialized operating and maintenance personnel. More important, as these resources are invested they create more demand. More resources are required to meet this new demand. When, finally, the system can no longer keep pace with the exponential increase in resources and increased flow, it can break down in many different ways.

The energy matrix represents a similar set of developments.

These began with similar attempts to increase efficiency. The daily hauling of wood and periodic deliveries of coal are replaced by gas or electric lines. To balance capacity against fluctuating demand, lines and systems are linked in support of each other. Both the efficiency and the failure of the great eastern power grid are the results of the logic of scale and a dependence on the network. Such systems also offer service and economy with an increasing risk of disaster. With each increase in the scale of operation has come more of a dependence on the workings of a central system. We have forfeited face-to-face contact at the same time that we have lost control of accessibility, quality, and the reliability of services which were initially designed to offer convenience. The same forces that push from dispersed low technology into centralized linear forms of technology are now pushing toward a new level. The layered networks of megasystems must be subjected to the same kind of scrutiny and consideration of efficiency which we once applied to pails and pipes.

We are at a fork in the technological road. The final columns of the matrix display two alternative tracks. Both contain technologies for high-performance incremental service systems. Both hold the potential for the elimination of linear systems and a move on to a high-performance dispersed form. One is capital intensive; the other is labor intensive. Each situation presents a different mix of needs and resource considerations; consequently, the alternative solutions should be examined in the context of a specific solution.

At the capital-intensive end of the scale, "black box" solutions require great resources to develop, build, purchase, and operate. But they require fewer man hours for installation and maintenance. For some situations, these systems are ideal. In other situations, the creation of jobs may lead a labor intensive society to a water delivery and waste removal system built on simple transport devices: carts, electric cars, holding tanks, and trucks. In many cases labor intensive solutions are not labor intensive in the sense that traditional hand delivery systems were. They may require some labor, a minimal amount, but more than the capital intensive solution. Once again, referring to the water treatment, waste water, and energy, one can see that the black box solutions include the functions of several matrices. Waste can be used to produce energy for the water purification process. The black box uses modern technology to accomplish in a sixteen cubic foot box what once required an acre of land. We can also see the possibility of installing a labor intensive piece of hardware (a holding tank can eventually be replaced by a black box.)

These concepts—reuse, individual control, and small scale—are the most critical to understanding the upper end of the technological continuum. We must qualify the word "high technology." Many of the systems described here do not utilize sophisticated hardware technology. Instead they result from a more sophisticated organization of existing utility technology. In some examples, the same basic solutions can be implemented with a variety of hardware. (In both high-rise urban office buildings and coastal Mexican villages, drinking water is delivered,by truck, in bottles.) In many cases the new incremental technology will be a traditional one that is viewed in a new light. These solutions will frequently call for a labor intensive activity rather than a capital intensive hardware solution.

Strategies

The technologies we have described make up a palette for the framers of public policy. There is no point in attempting to rank-order them or to select the most promising direction for future development. Instead we must describe each technology in a framework which will allow for a selection: a match of the technology against the requirements and the resources of a specific situation.

In each situation, specific physical conditions, resources, cultural thrusts, special interests and images will advance or constrain particular approaches. In each situation a particular strategy for innovation is called for.

Given the desire to develop a set of "incremental" technologies for urban service and support systems, two basic strategies suggest themselves. These might be called Trickle Down and Direct Attack. What are the implications of each in the situations we are considering?

Trickle Down

The trickle-down strategy assumes that new products enter the market in the hands of the affluent. As these products deteriorate, or as they are replaced by newer, better, or more fashionable products, they are passed down the economic ladder. Thus, while the U.S. automobile industry has never been able to produce a low-priced product, the used car market makes standard cars available to the poor as age and wear decrease their value.

Many sectors of the economy operate on this model: automobiles, household appliances, most housing, and even neighborhoods. Each goes through a typical life cycle. A luxury product is developed for sale to affluent households. Then, as age, wear, or changing fashion come into play, the product is passed down or the household moves on. Others, relatively lower on the income ladder, acquire it. Businesses are formed to trade in it, to repair and maintain it. The trickle-down process supplies useful products to the poor. In many cases (high maintenance automobiles, for instance) the product is inappropriate but useful. In other cases (deteriorated neighborhoods) the nature of the process keeps those at the bottom on the bottom. But in most cases, trickle-down provides useable products and the basis for a locally-based repair, parts, and service industry.

The service systems of developing nations are based on this process: the ubiquitous old buses, big cars, refrigerators, oil drums, and construction equipment. The trickle-down system can also work for the products of a new urban technology. New equipment to purify water, treat sewage, move people, and produce energy can eventually reach the poorer communities. The process will be slow and wasteful of energy and effort, but in many cases it will be the only way to make useable products appear. Certainly, as some of this equipment, developed for use in affluent resorts, second home communities, and the overcrowded urban fringe, trickles down, we can expect it to reappear as an aid to incremental development in less affluent societies.

Direct Attack

Direct-attack aims the development effort straight at the target population. The production of the Volkswagen is an example.

The principle constraint to direct-attack is the cost of development. The new technology may be expensive. Long lead times and major capital investment may be called for. The eventual market for the product is uncertain. Will it be accepted? Will there be demand as well as need? The problem of aggregating future markets is a difficult one. Subsidy or third party support of research and development can be expensive and uncertain. The time, cost, and eventual shape of the innovation are also uncertain. Often, those least able to afford it are experimented with. The target population tends to ask "Why me?" rather than "Why can't I have that?"

On the other hand, the problems of expensive and sophisticated new technology can be avoided. Low technology innovations often lend themselves to direct-attack. This can mean simple and direct applications of existing hardware, community organization and participation, and redefinition of the problem. Again, key inputs of information or equipment may make direct-attack effective. Seed money or short-term investment can be effective in moving a system into a new role.

For some areas of urban service technology, projects in developing countries can provide an attractive market. If aggregated and guaranteed by a national or international government, such a market can serve as a carrot. Large industrial organizations will respond and develop new hardware with this market in view. Aggregating and guaranteeing a market typical of others in similar communities will make an even more attractive carrot. In some areas, direct-action can provide a workable mechanism while the trickle-down mechanism is operating; in other cases, trickle-down will provide the holding situation while direct-attack is prepared.

Clearly, a broad attack on the problem of developing incremental infrastructure technologies will consider the use of trickle-down and direct-attack in combination.

Which of these strategies shall we choose?

Both of them!

Strong pressures exist for the introduction of new utilities technologies and strategies in the more developed countries. Suburban tract builders, constrained by existing utilities systems; resort, recreational and new-town builders as they face an array of new controls; all can be expected to call for the development of expensive new products. This research and development and the related new products, codes, and images will trickle down to lower-income communities in developing areas.

At the same time, selected programs of market aggregation, needs definition, and product development will attack other problems directly. Some of these solutions will apply new concepts and management tools to existing technologies; others will introduce new technologies through the market aggregation—and/or reserach development route. The products of more affluent societies will trickle down and find their way into use.

New understanding must emerge, and with it new institutions, codes, regulations, and images. These will help activate community response and aid the flow of new techniques into the culture and context of the society. The professional and the institutions within which he operates will recognize the broad spectrum of techniques at their disposal. They will be experts at defining the range of possibilities, from labor-intensive, individually-controlled systems through large, linear urban networks, to a host of new black-box technologies. And they will see a variety of roles in selection, adaptation, transfer, and development.

As national governments come to understand these mechanisms, they can support them. Certainly they can aid in the product definition-market aggregation process. They can adjust import priorities and regulations to support the trickle-down process.

As the infrastructure requirements of both developed and developing nations approach each other, a new symbiosis will occur. For in fact, the process by which developing nations meet their housing needs can serve as a model for a truly modern building industry.

FIGURE 1

A NEIGHBORHOOD FOUNTAIN IN A NORTH AFRICAN VILLAGE. INDIVIDUALS MEET IN THE VILLAGE SQUARE AND CARRY WATER TO THEIR HOMES.

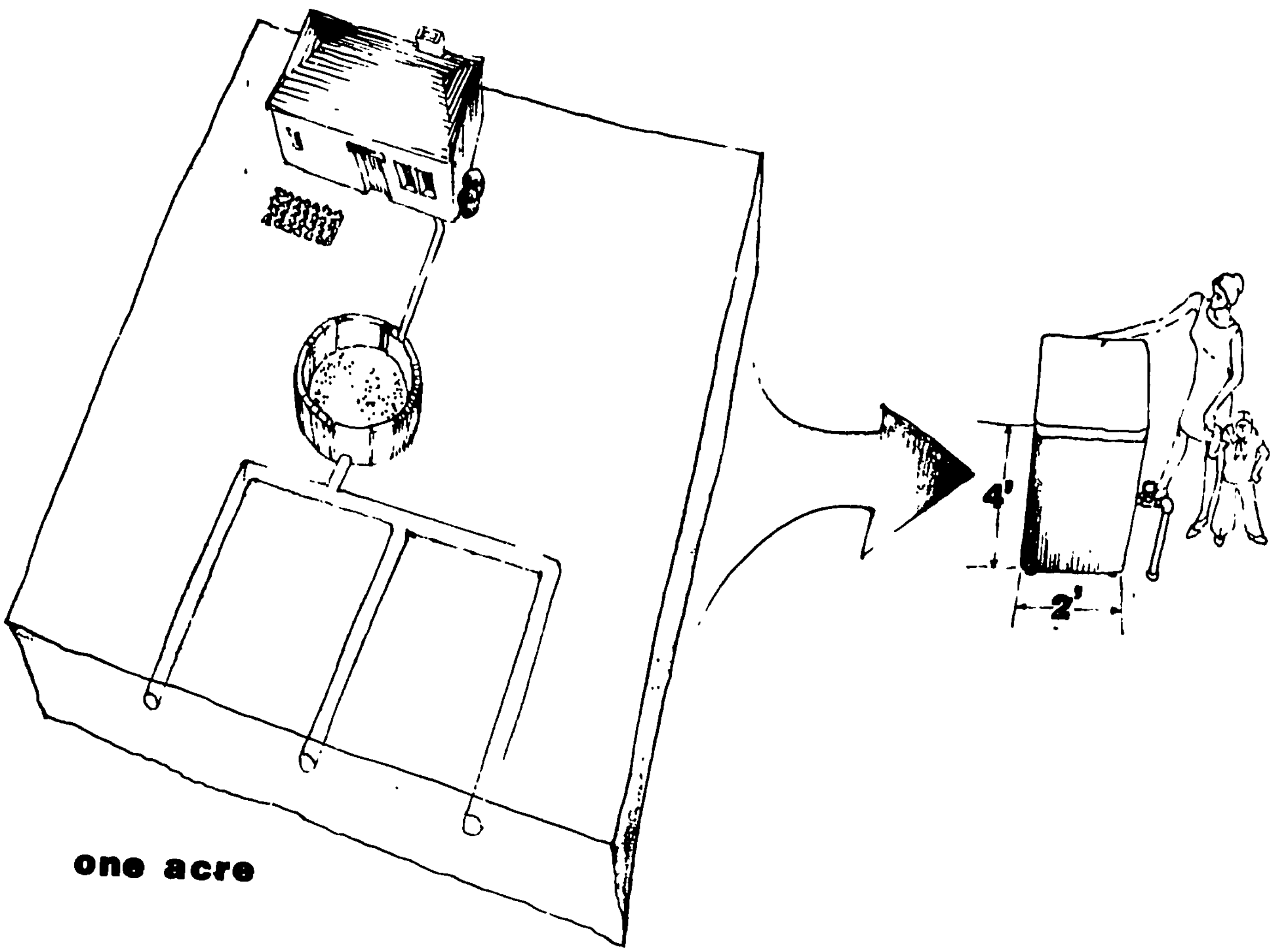


FIGURE 2

COMPARISON BETWEEN A TRADITIONAL RURAL SYSTEM AND A "BLACK BOX". THE BLACK BOX USES A HIGH CAPITAL INVESTMENT TO REPLACE AN ACRE OF LAND WITH A REFRIGERATOR-SIZED PIECE OF HARDWARE.

FIGURE 3

IN MOST BUILDING CLUSTERS, A TANK-TRUCK CAN PUMP WASTE OUT OF A COMMON HOLDING TANK AND TRANSPORT IT FOR PROCESSING AND USE AS FERTILIZER. AS ADVANCED HARDWARE BECOMES AVAILABLE, A "BLACK BOX" CAN REPLACE THE TANK AND NEITHER TRUCK NOR PIPES ARE REQUIRED.

FIGURE 4

THESE SKETCHES ILLUSTRATE THE TRANSFORMATION FROM A RURAL DISPERSED SYSTEM THROUGH THE LINEAR STAGE AND ON TO A HIGH DENSITY, HIGH PERFORMANCE DISPERSED SYSTEM. WELLS AND PRIVIES ARE IMPROVED WITH PUMPS AND CESSPOOLS. A LINEAR WATER SYSTEM COMBINED WITH A SEPTIC TANK IS USED UNTIL A FULL LINEAR SYSTEM ARRIVES. FINALLY, NEW TECHNOLOGY ALLOWS INDEPENDENT DISPERSED HOUSING AT HIGH DENSITY.

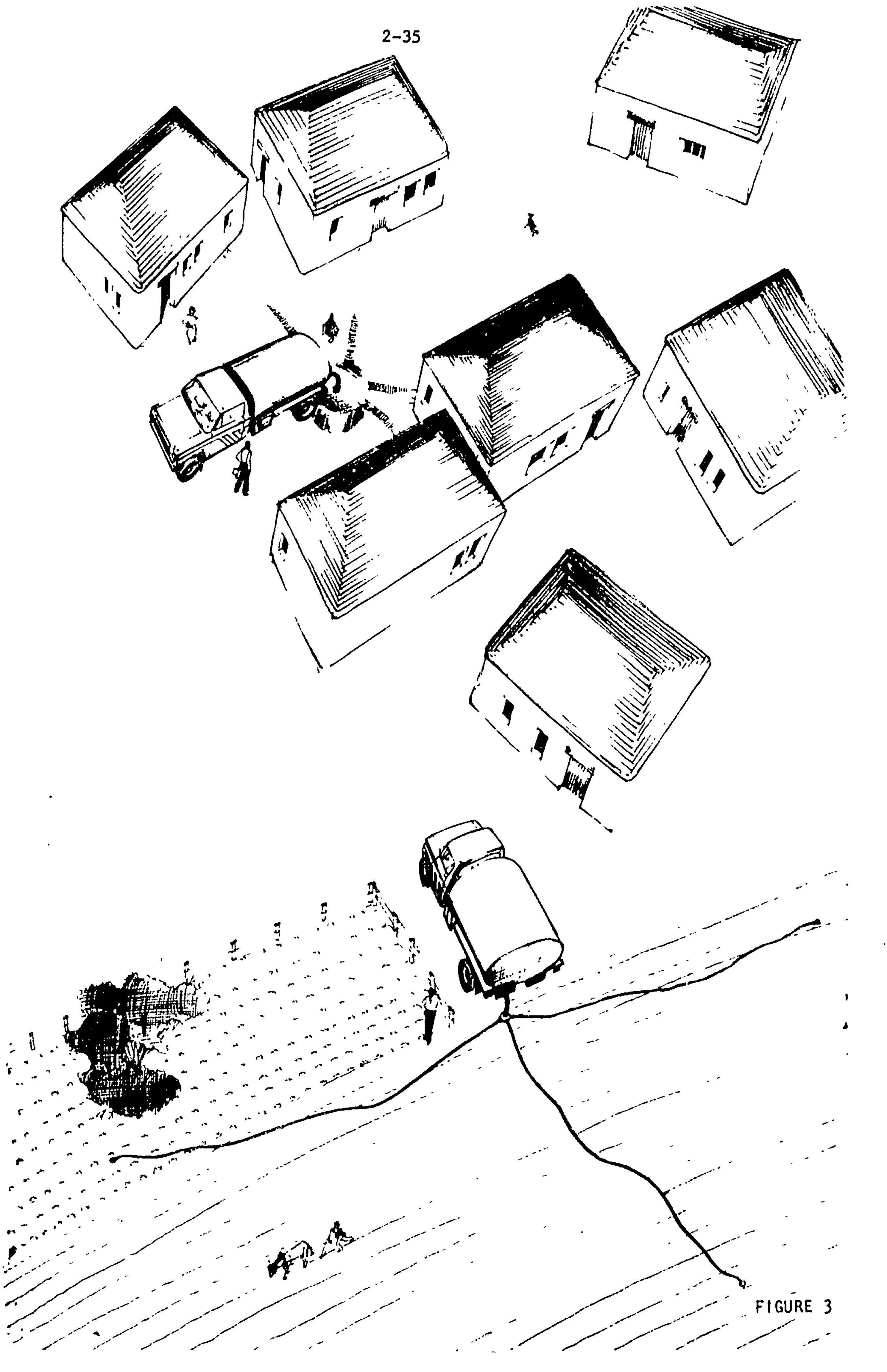


FIGURE 3

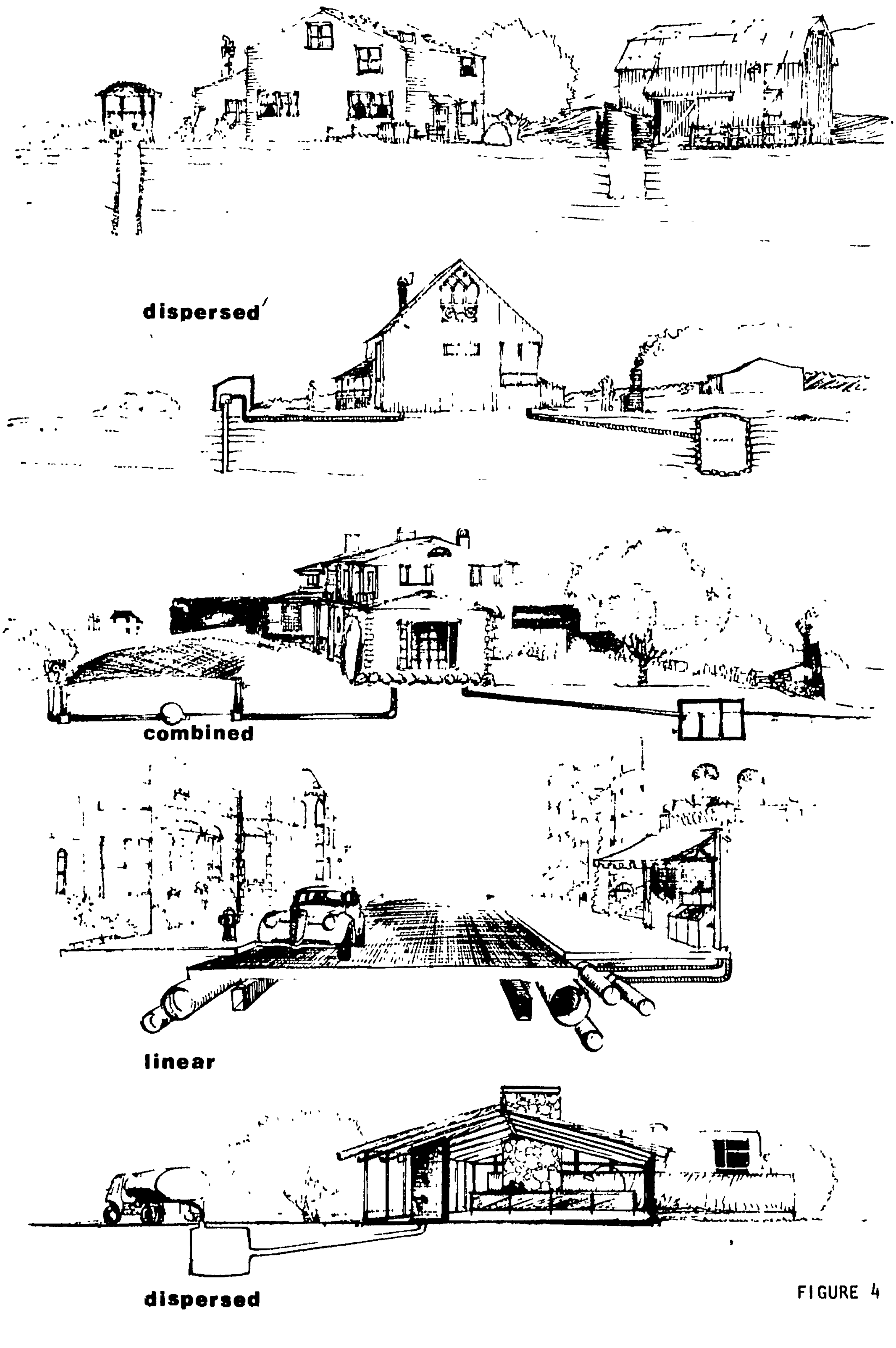


FIGURE 4

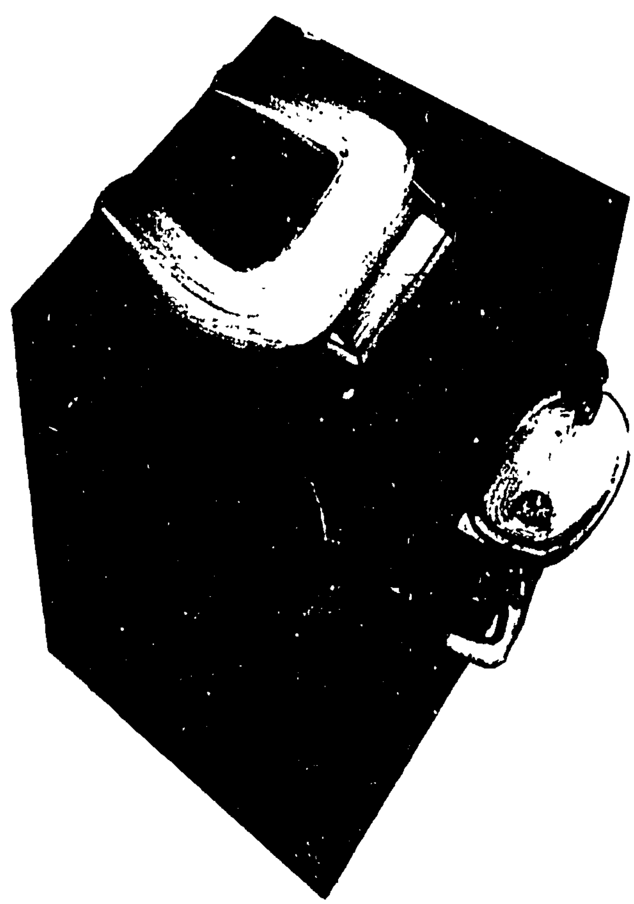


FIGURE 5

ARTIST'S CONCEPTION OF A "BLACK BOX".

SELF-HELP INFRASTRUCTURE

Applications of Irregular, Small-Scale, Incremental Systems for Residential Utilities

Presented at the M.I.T. Symposium on
Strategies for AID Programs in Selected
Areas of Science and Technology
April 23-26, 1974

Ian Donald Terner
Associate Professor, M.I.T.
in collaboration with
Anne Aylward
Byung-Ho Oh
Abby Rashid

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Introduction

One of the great tragedies and ironies of our time is the worldwide toll of suffering and death attributable to the lack of basic sanitary facilities and services. Science and technology have long since advanced to the point where this might have ceased to be a problem; and indeed some of the industrialized nations have made substantial progress in this area. In contrast, much of the developing world is still severely plagued by the problem. In fact, virtually none of the large cities of the third world have yet been able to extend water and sewer service to all residents -- nor is there any hope of their doing so in the near future.

This paper asks what scientific and technical strategies might feasibly address the problem. Unfortunately the stock answer, i.e., the simple quantitative provision of more and bigger versions of existing technology is not acceptable. This is so because although technologies are theoretically available, solutions have not been implemented for fundamentally political and social reasons. Thus, technologists have tended to shy away from the area, viewing the problem as "solved." All that is needed are the resources and political will to implement existing solutions. But if the will is not there, if the resources are not forthcoming, can the technologist simply shrug and move on to the next problem? Is there any further role to play?

This paper argues that there is. It suggests that if the resource commitments are not at hand, nor on the horizon, then the technological challenge (as always) is to do the job with fewer resources, and perhaps also with a different mix of resources.

This alternative, then forms the theme of this paper. It identifies unskilled, uncoordinated, individually motivated and controlled self-help labor as a potential resource which might be brought to bear on the problem of the millions of urban households presently unreached by existing municipal infrastructure. The concept is one that has received fairly broad, though recent, official acceptance in the area of housing, following the pioneering work of John F.C. Turner. However, with respect to infrastructure, the concept is more difficult to justify and much less well regarded -- for both practical and ideological reasons which will be discussed below.

First, however, it will be important to offer a rather narrow definition of infrastructure for purposes of this paper, and then to view the overall dimensions of the problem.

Infrastructure is generally defined as those facilties and services which support human settlement. It can include water provision, sanitary and storm sewage, electric energy, gas, solid waste disposal, roads and walkways, schools, clinics, open spaces, markets, public transit, etc. For the purposes of this paper we will concentrate on water and sewage -- two related services which clearly have the most direct and dramatic impact on human survival. The technology associated with these services in urban settings has generally been assumed to be the responsbility of fairly large collectivities: municipalities, regions, or nations. Yet these large collectivities have failed at a massive scale to provide adequate service for urban dwellers, while showing a systematic bias against the poorest urban residents, particularly those millions of inhabitants of squatter or spontaneously settled areas. Yet squatters have provided for themselves many smaller-scale, "irregular" substitute elements of infrastructure, notably schools, walkways, roads, storm drainage, markets, etc. However, the provision of water/waste services has defied small scale irregular attempts by individual households or small clusters. It is important to consider the results of this massive failure by public authorities coupled with the inability of individuals or small groups to fill the void for themselves.

STATEMENT OF THE PROBLEM

Water

Billions of person-days of labor are lost annually because of illness caused by water-borne diseases, particularly from water which has been polluted by raw sewage and other wastes. The households which can least afford this economic loss are those of the squatter areas where such disease is most rampant. Water plays a predominant role in the transmission of enteric bacterial infections such as typhoid and paratyphoid fever, bacillary dysentery and cholera. It also plays a role in the spread of numerous other infections.

In most squatter areas there is no provision of piped water to residences. Water is sometimes available from tank trucks, public standpipes, or fountains, often outside or on the periphery of the settlement. In many cities this water is available only intermittently.[1] Tremendous amounts of time and energy are diverted from other productive activity to stand in line and carry water, often up extremely difficult and steep slopes which characterize many squatter areas. Since the amount of water which may be carried

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1 Jerome, Axel. "Toward the Solution of the Squatting Problem in Haiti", Department of Urban Studies and Planning, MIT, Cambridge, Mass. 1965

is limited, it is used for drinking and cooking, leaving little for personal and household hygiene, adding to the probability of disease. Lack of available water also increases the difficulty of waste disposal, adding to the problems discussed below.

In areas where water is drawn from wells rather than public pipes, the chances of pollution of the groundwater, and thus the well supply, are extremely high and have in some cases led to strict, but not always effective, zoning to protect municipal wells.

<u>Waste</u>

A functioning waste disposal system is also a critical component of a healthy community. Its absence means that the healthy are continually exposed to the diseases of the unhealthy; evidences of reduction of the incidence of disease with introduction of proper sewage disposal is dramatic. Children are particularly susceptible to diseases caused by poor sanitation and improper disposal of human waste. It is estimated that five million children die each year from such causes.[2] The productivity of the adult population is substantially lowered by illness; this includes not only direct economic productivity, but also interest and energy directed toward improving the living environment. These are social and economic costs directly attributable to poor sanitation.

Inadequate treatment and disposal of human wastes not only results in contamination of the water supply, but also attracts flies, rodents, and other animals which bear disease. Open sewage ditches and garbage heaps are particularly inviting places for children to play, compounding the health problem.

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[2] U.N. Conference on the Application of Science and Technology for the Benefit of Less Developed Areas, <u>Health and Nutrition</u>, U.S. Government Printing Office, Washington, D.C. 1963

Many squatter areas experience serious problems of waste disposal -- ditches which carry waste away in the dry season flood in the rainy season; or ditches which drain adequately in the rainy season stagnate in the dry season. Some squatter settlements, built on marginal land, are regularly flooded during heavy rains.

Link between Water and Waste

The problems of water supply and waste disposal are inextricably linked -- both positively and negatively. On the negative side, inadequate waste disposal is a primary cause of water pollution and thus the transmission of disease. Inadequate supply of water makes disposal of waste, particularly human waste, more difficult, also increasing the risk of infection. The two problems reinforce each other, forming a vicious cycle of infection, disease, and re-infection.

On the positive side, treated waste water can be an important water resource. Serious water shortages exist or are predicted in many parts of the world as the demand for water increases and the supply, recharged only through precipitation, remains static, or in some places diminishes due to man's alteration of ecology and micro-climate. In this context of growing demand, treated waste waters constitute an increasingly important element of total available water.

In order to meet the basic needs of the population while at the same time safeguarding the future, rational resource management is imperative. Specifically, it is necessary to reduce to a minimum the negative environmental effects of waste disposal and, where possible, to recycle wastes for productive purposes. The clear link between water and waste. coupled with the large failures by public authorities to provides services in these crucial areas, makes the development, mass production, and distribution of self-sufficient systems to recycle waste water for the individual household or community an important priority.

Magnitude of the Problem

The magnitude and universality of the problems discussed above is demonstrated by the following array of brief examples from both the developed and the developing countries around the world:

- In Great Britain 23% of households do not have individual bathrooms.[3]
- In France only 80 out of 3800 local municipal authorities have sewage treatment plants; fewer than 1500 have any kind of sewage or refuse disposal system.[4]
- In India and Pakistan 40% to 70% of the population is infected by hookworm, in Ceylon 80% of the population is infected.[5]
- In north China, 81% of the population tested positively for ambiasis.[6]
- In Honduras, 60% of the school children were found to have ascaris, 50% to have hookworm. It was estimated that hookworms metabolize more food than people! [7]
- In Haiti, squatters use latrine pits, approximately one for every four households. These pits flood in the rainy season and are unusable, causing disease. Public latrines, cantilevered above the sea have been proposed as an alternative.[8]
- In Mexico City it has been estimated that there is one bathroom for every 298 people. 10% of the households have septic tanks, 40% use latrines, 50% have no formal system of waste disposal.[9]

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[3] Wagner, Edmund G. and Lanoix, J.N., Excreta Disposal for Rural Areas and Small Communities. World Health Organization, Geneva, Switzerland, 1958.

[4] ibid.

[5] ibid.

[6] ibid.

[7] ibid.

[8] Jerome, op. cit.

[9] ibid.

- In Lagos, in 1960, 85% of 4759 school children examined had parasties; dysentery and diarrhea accounted for 10% of all deaths and 54.5% of all deaths in children under 5. Excrement is collected in night soil buckets by 400 collectors and dumped into a lagoon at an annual cost of $600,000. However this system works erratically because collectors are often out on strike.[10]

- In Latin America, diarrhea is the leading cause of death in 8 out of 18 countries; in an additional 4 it was among the five principal causes of death.[11]

- Less than 5% of the urban population of Latin America is served by a sewage system.[12]

The total dimensions of the world's infrastructural needs are staggering: 70% of the population lacks adequate and safe water supply; 85 % of the population depends on primitive methods for disposal of waste.[13] The minimum cost for provision of this needed infrastructure using standard technology has been estimated at approximately U.S. $1000 for a household of five persons. Assuming that 70% of the world's population, or 2.5 billion persons, are presently unserviced, this would mean extending service to 500 million additional households (@ five persons per household)at a cost of $1000 per household. Such work would yield a total cost of U.S. $500 billion. This figure, although astronomical is not infinite; it represents six months GNP of the United States.

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10 Abrams, Charles. Man's Struggle for Shelter in an Urbanizing World. MIT Press, Cambridge, Mass. 1970.

11 U.N. Conference on the Application of Science and Technology, op.cit.

12 ibid.

13 People and Living, Volume V of Science and Technology for Development. United Nations, New York, New York, 1963.

The Example of Seoul, Korea[14]

Seoul provides a graphic example of a primate city in a developing country struggling to meet the infrastructural demands of a rapidly growing urban population. The following brief description summarizes the dimensions of the problems faced by many municipal governments and typical costs for infrastructure which is being installed in an effort to meet the needs of the expanding populations.

In 1970, Seoul had a population of about 5.5 million, in an area of about 223 square miles. Its central water system was completed in 1908 with a production capacity of 13,600 tons per day, supplying 122,000 people (50% of the population) with about 29 gallons per person daily. As a result of continuous expansion, the municipal system had a capacity of 1.3 million tons daily in 1971, enough to supply just over 5 million people (a relatively high 86% of the population) with about 66 gallons per person daily. However, only half the amount (33 gallons) is delivered to users due to leakage, which will be discussed below.

A major problem in Seoul is insufficient water resources. Throughout Korea there is a seasonal shortage of water, which has been aggravated by the sharp increase in demand for water following the rapid industrial development, urbanization of population, rise in living standards, and modernization of agriculture in recent years. In 1967 the Water Resources Development Corporation (WRDC) was organized to handle the worsening situation.

Flooding is another serious problem. The lower parts of the city flood every summer due to heavy seasonal rainfall. The

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14 Byung-Ho Oh, "The Infrastructure Needs of Seoul, Korea", unpublished paper, Department of Urban Studies, MIT, 1974.

city's obsolete drainage system is unable to handle the large amount of rainwater. In 1971, property worth nearly U.S. $4 million was lost in the flooding, scores of people died, over 10,000 buildings were destroyed, and more than 2,000 people were left homeless.

The WRDC has completed two major projects on the Han River which runs through Seoul. The first was construction of a model to test flood control on the river at a cost of nearly U.S. $3 milli 60% of which was funded by U.S. foreign aid. The second project was the construction of a multipurpose dam at a cost of nearly U.S.$80 million, 28% of which was a Japanese investment. The dam will help to control seasonal flooding and regulate annual water supply to Seoul.

As mentioned earlier, the age of the municipal water system causes serious distribution problems. In 1968 roughly 50% of the purified water leaked from the pipes before reaching users. The rigid physical system and density of settlement make repair of the pipelines difficult. In 1968 over U.S. $3 million was spent to repair less than eight iles of pipeline. Although the amount of water purified by th system increased by 140% between 1956 and 1972, the amount actual y reaching users increased by only 30% during the same period due to leakage.

Seoul has nine water treatment plants and three sub-treatment plants to purify water. In 1971 approximately U.S. $8.5 million was spent for management and maintenance. Categorized, these costs were 20% for electricity, 10% for chemicals, 20% for personnel and labor, 20% for repairs, and 30% for other expenses. The average charge to consumers was about U.S. 5 cents per ton.

The water quality of Seoul is seriously threatened by the sewage system and other methods of excrement disposal in the city. It is estimated that 2.7 million liters of excrement are discharged daily; while the city is only capable of collecting and processing about 80% of that amount. The sewage system is very old and modernization efforts have only been undertaken recently.

In 1973 the city installed 48,000 units of a modern flush toilet system in 15 dongs (a local district of about 1/3 square mile and about 15,000 residents). The new system is scheduled for installation in an additional 50 dongs in 1974. However, much of this sewage is dumped untreated into the Han River, jeopardizing the water quality. Recognizing this problem, the city recently built a sewage treatment plant with a daily capacity of 25 million tons at a cost of nearly U.S. $9 million.

A major problem with the collection of wastes in Seoul, particularly in areas not served by the sewage system, is the poor road network. There are many areas where it is impossible for service vehicles to pass through. Service personnel must therefore carry buckets to and from collection vehicles. This sector of the system is also in need of investment and modernization. The city operates over 200 vehicles for the collection of human wastes. 20% of these are over 15 years old and in need of replacement. Nearly 7,000 men are presently employed in waste collection and disposal at a daily cost of approximately U.S.$40,000 ($1.80 per worker per day). This low wage and the low regard with which such work is traditionally viewed make recruitment for these jobs a problem.

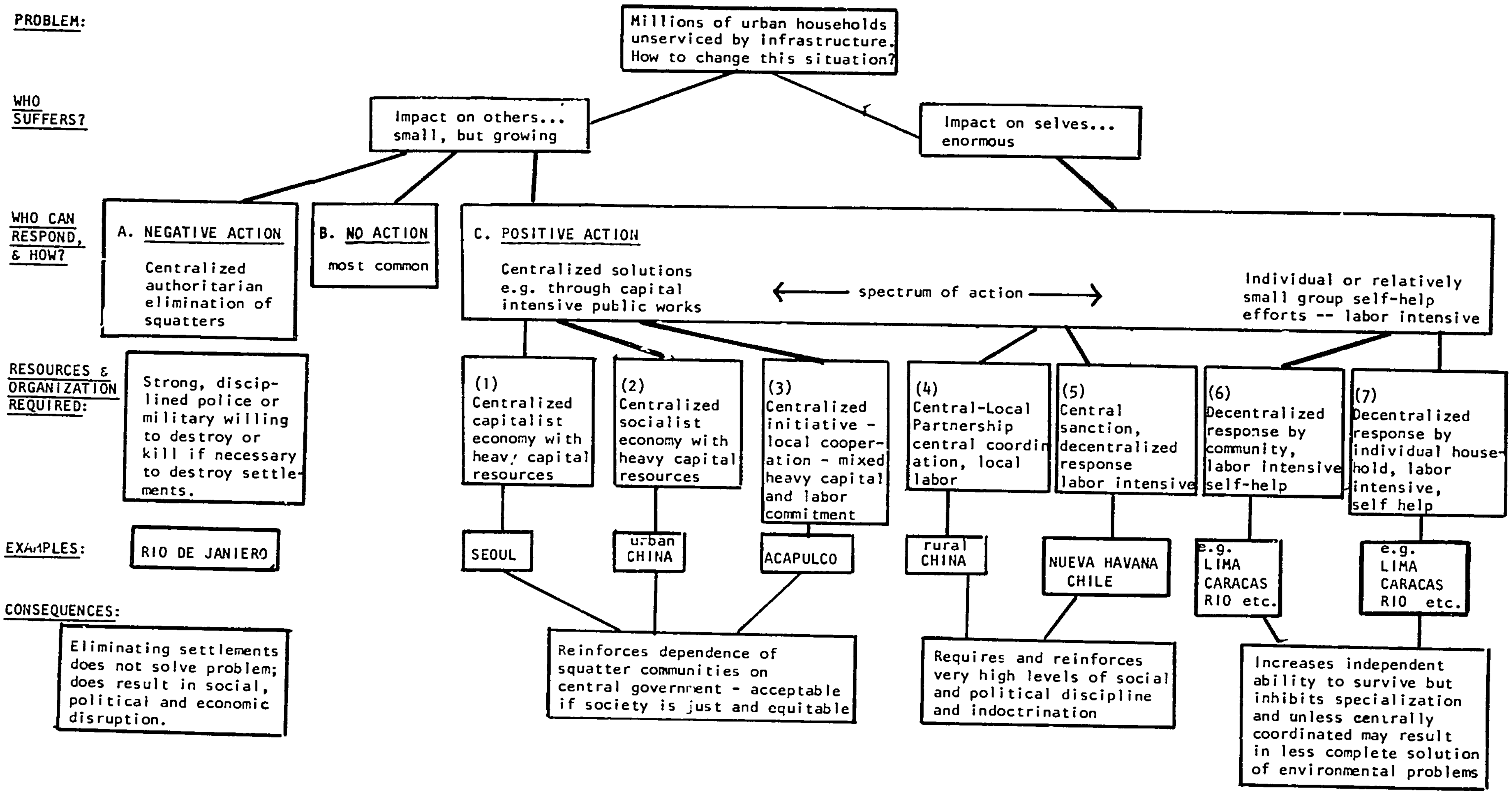
These figures begin to indicate the costs and scale of the problems caused by rapid urbanization for a city such as Seoul, with an old and inadequate infrastructure and limited funds.

In sum, there is tremendous worldwide need for adequate techniques to provide infrastructure, particularly water/waste systems in the rapidly growing urban areas. In both developed and developing countries, urban settlement is increasing much faster than urban services and the capability of institutions responsible for their provision. Housing and infrastructure lag far behind need, resulting in an overall decline of environmental quality. In the area of housing, particularly in developing countries, individual households have filled the gap left by the failure of urban institutions by buildings their own homes. In the area of infrastructure, however, it has generally been accepted that individuals are unable to provide for their own needs. This disucssion questions that assumption.

TRADITIONAL RESPONSES

This section of the paper discusses the range of responses which governments and individuals have employed to meet their infrastructure needs. The range of responses, the resources and organization required by each, and the probable consequences are diagrammed in Figure 1. It is suggested that there *is* precedent for the use of self-help methods, not only for housing, but also for infrastructure. We further suggest that as technology develops, allowing incremental provision of infrastructure and recycling of water by the individuals or small groups of households, self-help activity in these areas can become increasingly viable.

The traditional responses by government to the need for infrastructure have been to act positively by providing infrastructure; to act negatively by eliminating the squatter settlement; or, most



IGURE 1: TRADITIONAL RESPONSES

often, not to act at all. The choice of response depends largely on the ideology of the government and its resources.

The intensity of the impact of the lack of infrastructure is also an important factor in the response. This impact occurs at two levels: the internal impact on the residents of the unserviced areas themselves, and the external impact on the conventional economy and population of the surrounding society. Examples of the latter situation include situations where the topography causes raw sewage from the squatter areas to drain down into wealthy residential areas (e.g. Acapulco), where the squatter areas visually blight the tourist areas (e.g. Rio), or where the proximity of the squatter areas to wealthier residential areas arouses fear of epidemics or fire (e.g. the Mathari Valley in Nairobi).

However, most often the internal impact becomes intolerable long before the external impact is sufficient to provoke central government action at more than a token scale. In this default situation squatters are forced to continue living under intolerable conditions, or to consider escalating levels of political activism, and/or options of individual or community self-help. The internal and external impact of the lack of infrastructure are important elements in the government's choice of response.

By far the most common response is to ignore infrastructure in squatter areas (see [B] in Figure 1). This may happen because the conditions of the squatter areas do not have sufficient external environmental impact to demand a solution, because the squatters lack political power to effectively demand a solution, or because the government, despite recognizing the problem, lacks some combination of the will or resources to implement a solution either by elimination of the settlements or by provision of infrastructure. In each of these cases the government will ignore the problem, allowing the settlements to continue without infrastructure.

A second category of response is the elimination of squatter settlements, thus removing the apparent environmental problems which they cause (see [A] in Figure 1). This choice has often been made by governments sufficiently authoritarian to destroy settlements and, if necessary, kill people. This most often happens when the settlements have a direct negative impact on the external environment, as in Rio de Janiero where the squatter areas visually blighted the tourist areas.

Although physical elimination solves the short-term problem, the environmental problems caused by the lack of infrastructure simply move with the squatters to another site. Additional problems may be created by the disruption of the squatters' social and economic environment, and often the external economy of which they are an important part.

In some cases, a government ideologically inclined to eliminate a squatter settlement has recognized the integral relation of the squatters to the local economy and allowed them to remain. In other cases, this recogniztion has occured only after the destruction of the squatter areas and the serious disruption of the economy.

A third category of response is the provision of infrastructure for squatter areas (See [C] in Figure 1). This response varies depending on the government's ideology and resources, ranging along a spectrum from centralized action by the government, tying these areas into the regular system (e.g. Seoul); to decentralized self-help action on the part of the squatters to improve their own conditions, either by legally plugging into the regular system (e.g. Lima), illegally tapping into the regular system (e.g. Bogota), or establishing a separate "irregular" system (e.g. Manila). This spectrum includes the possibility of combinations of centralized initiative and self help labor, centralized initiative for irregular systems, etc. Examples are discussed in more detail below.

At the present time, activity is primarily focused at the centralized end of the spectrum. Infrastructure has traditionally been perceived as a "public good" and its provision presumed a responsibility of the government. However, squatters are frequently recent migrants from rural areas where waste disposal and water provision are more often the responsibility of the household than of the government. Perhaps, then, there are traditional skills which may be utilized in the denser and more complex urban settlements. At the very least, an effort should be made to retain the household's sense of responsibility for participation in provision of its own infrastructure.

This perception of infrastructure provision as a government responsibility has been reinforced by the demands of traditional technology which have dictated a centralized and rigid response (as exemplified by the grids and pipe networks of municipal sewer and water systems). Emphasis should be placed on the exploration of incrementalized provision of infrastructure, allowing gradual upgrading and expansion as is now possible with housing. This would allow increased options for self-help action in infrastructure development. Problems of over-capacity, high capital investment and other diseconomies of scale would be substantially reduced. More flexible technology would allow greater freedom of choice along the centralized/decentralized (or governmental/self-help) spectrum.

Experiences at several points along this spectrum are described below, corresponding to the diagram in Figure 1 (see (1) through (7)). For each example it is important to consider the stimulus for action, the ideology of the government, the level of capital required and the type of technology employed.

The seven case examples group in three clusters: First, centrally or governmentally initiated and implemented infrastructure service, including the cases of (1) Seoul, Korea; (2) the urban areas of the Peoples' Republic of China;

and (3) Acapulco, Mexico. Second, there are two transition cases, which illustrate a combination of government action and support, coupled with localized small scale initiative and implementation work, as seen in (4) rural China and (5) Nueva Havana, Chile. Finally, there are two examples of small scale initiatives, unsponsored by and often in defiance of the government, as seen in squatter areas worldwide.

Cluster One: Centralized Responses

Case (1): Seoul, Korea -- The response of the Seoul government discussed in detail earlier, is a typical example of a centralized, capital-intensive means for providing infrastructure. The response was based on standard technology -- large dams, purification plants, sewage treatment plants, and rigid linear pipe grids. The capital expenditure was enormous, involving large amounts of borrowed foreign capital. Local initiatives or participation in planning or building the system were virtually non-existent, and over a million residents of the poorest neighborhoods in the city are untouched by the system. The city has still not solved the problem of replacement of worn out pipes in densely settled areas, nor the problem of servicing areas unsuited to the conventional pipe systems (steep hillsides, etc.).

Case (2): Urban China -- Infrastructure provision in urban areas of the Peoples' Republic of China provides an example in which large amounts of both labor and capital have been expended in developing infrastructure to serve a high proportion of the people. This centralized response, similar to that described for Korea, includes the construction of massive dams for flood control and hydroelectric power and major municipal infrastructure systems. The difference between China's response and that of Korea is reportedly that far fewer areas have been left unserviced and that the motivation or stimulus for action is quite different. Whereas under a capitalist economy the lack of infrastructure for the lowest income areas most often must adversely effect the economy and environment of the external society before action is taken, in China such action is apparently undertaken within an ideological framework, i.e. as a basic right of all households to have adequate water and waste facilities.

This type of response can reinforce the dependence of populations on central government; however, such dependence can be acceptable if the government is reasonably equitable and thorough in its distribution of service.

Case (3): Acapulco -- Acapulco, Mexico provides an interesting example of a basically central government response which begins to include some consultation with and participation of the residents of the squatter areas. It is a classic example, however, of a situation in which the impact of the lack of infrastructure within the squatter areas on the external environment was so detrimental that after years of ignoring the situation, the government was forced to take action. The squatter settlements of Acapulco are located on the mountainsides above and around the town. The sewage and refuse of the squatter areas flowed down the hillsides into the wealthy residential and tourist areas below and into the ocean. As the squatter population of Acapulco grew, so did the problem -- with tourism as the backbone of the local economy the lack of infrastructure was having such detrimental effects on the beauty and tourist attractions of the city that the government was forced to act, in stark contrast to its inaction in other squatter areas, particularly those around Mexico City. The integral role of squatters in the labor force in hotels and other tourist facilities precluded their removal.

Once the government decided to act, it did work with the squatters to plan two phases of development. During the first phase water and sewer pipes, paved roads, concrete house foundations, communal sanitary facilities and individual water taps were installed. During the second phase a bathroom and kitchen were installed in each house. For each phase the government provided the capital and expertise and hired the squatters to do the work. Thus, in this case there was some local participation, although virtually no local influence on the basic decision to act.

Cluster Two: Transitional Responses

The cases referred to in this cluster represent a transition between highly centralized government responses and dispersed "irregular" responses by individuals and small groups. Both cases reflect a kind of working partnership between central government and local groups.

Case (4): Rural China -- The rural areas of China provide examples of responses which emphasize local labor and initiative, particularly at the level of the rural commune or cooperative. In such a situation the residents work together to provide their own infrastructure often with the support of machinery and materials provided by the central party. Such a response allows the use of limited capital resources to service a much higher percentage of residents than would be possible with a standard capital-intensive response, and more easily than would be possible with an all-labor response. The impetus for this cooperative action comes both from the needs of the people and the ideology of the central government. While the quality of service provided and the level of technology employed may both be lower than would be achieved under a more common centralized response, the service is adequate to meet the needs of the community and reportedly represents an immense improvement over the previous conditions in China and over comparable conditions in many developing countries.

Case (5): Nueva Havana -- The accomplishments of developing infrastructure on the part of Nueva Havana, a cooperative Marxist encampment of about 450 households during the Allende government in Chile, provide an example of a response which falls on an intermediate portion of the spectrum between central and individual action. Although the efforts of Nueva HAvana were sanctioned, and in some ways supported, by the central government, the actual response was communally initiated and implemented. As with the previous example, this type of response required an extraordinarily high level of organization and discipline on the part of the community and can also result in somewhat lower standards of quality of service than a standard water and sewer system. The communal system developed by Nueva Havana was a distribution system only, and depended on plugging into centralized generating and supply facilities constructed by previous governments. Connecting the encampments's irregular distribution network to the central system was permitted in this case by the Allende Government, however there are also examples of "tapping in" without permission as in the settlement of Policarpa Salavarieta in Bogota, Colombia or central city settlements in Athens, Greece. (The vulnerability of such a system to the whims of the government is illustrated by the fate of Nueva Havana which has reportedly been destroyed by Chile's miltary junta.)

Both the Chinese and Chilean cases above have placed heavy reliance on very large measures of social discipline and political indoctrination. This has been necessary in order to combat the human tendency of "letting the other fellow do it," which is a variation of the social paradigm known as the Prisoners' Dilemma.[15]

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15 This discussion is an application of the classic social paradigm known as the "Prisoners' Dilemma," which posits two criminal suspects apprehended by the police and interrogated separately. The police know they do not have sufficient evidence to hold the suspects unless the suspects confess or can be induced to implicate each other. To provide that inducement, the police threaten severe sentences if the suspects do not cooperate, but are convicted anyway; and leniency to each suspect if he implicates the other. Hypothetical sentences are arrayed in the following matrix:

SUSPECT A

SUSPECT B		cooperate	not cooperate
	cooperate	A: 7 yrs B: 7 yrs	A: 10 yrs B: 0
	not cooperate	A: 0 B: 10 yrs	A: 0 B: 0

In collective or mutual self-help projects such as a single dwelling being undertaken by a family group the problem is minimized; all participants are highly visible to one another, all will directly and immediately benefit from the dwelling and there are natural leadership and functional roles already established. As the project grows in scale and requires more participants, who then become more anonymous and less visible to one another, authority and leadership problems arise and the concept of self-help becomes increasingly difficult to implement. It is therefore no surprise that the examples cited in this cluster (including the one from Bogota) are highly disciplined Socialist political cells which rely on vigorous political indoctrination from early childhood. Thus, an important rule of self-help emerges: the smaller the project (and the group involved) the more feasible it becomes. The larger the group, the more stringent the disciplinary measures required. This rule speaks directly to the performance criteria for self-help infrastructure technology: the smaller the service unit, the more feasible it becomes for self-help application -- particularly where these applications are prompted by the default of central government. More will be said later in the paper about the performance criteria for self-help infrastructure technology.

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[15](cont.) Clearly if both prisoners are disciplined not to talk, their collective interest is best served, they both go free. If only one implicates the other, the implicator may go free, and his partner would suffer the harsher 10 year sentence for not cooperating. If the discipline completely breaks down (as it most often does) both prisoners receive the more lenient 7 year sentence but their collective interest is least served, since their sentences total 14 years, compared to totals of 10 years or zero for the other options.

The paradigm exemplifies the necessity for disciplined cooperative action if the common good is to be best served. For example, in a collective self-help project, if the efforts and commitments of other participants are in any way doubted, the tendency is to ask "Why should I be punished more severely and all alone, when I'll probably be implicated by the other fellow anyway?"

Cluster Three: Unsanctioned and Unsupported Self-Help Responses

This final cluster of cases is drawn more generally from worldwide squatter experience. All represent small scale initiatives, leading to individualized and relatively uncoordinated actions at the household or small neighborhood scale. Unlike the transitional cases of the preceding cluster, they represent far less disciplined and structured efforts.

Case (6): Worldwide Squatter Areas, e.g. Lima, Caracas, Rio, etc -- There are numerous examples where irregular systems of infrastructure have been developed communally using self-help methods. The experiences of communities in Lima, Caracas and Rio are such examples. Although the arguments for and against such self-help are discussed in detail later, it is important to note here that the most successful projects of this type has been small-scale "irregular" systems, independent of the regular municipal system. Examples include housing, schools, religious and recreational facilities, access ways, and transport. Moderately successful efforts have been made in developing drainage and electrical power systems (the latter through distribution from illegal taps into the municipal system).

The areas in which communal self-help methods have been the least successful (and least frequently attempted) are the provision of waste and water systems. This is in part a function of the nature of the standard solutions to these problems, the prohibitively high level of capital necessary to communities with no capital accumulation, the rigidity of the traditional network, and the difficulty of its application to areas of dense existing housing and difficult topography. Moreover, the communal nature of these types of networks makes a high level of organization more necessary for these systems than for other infrastructure. In cases where irregular systems have succeeded they have almost always involved "plugging-in" (with legal sanction as in Lima) or "tapping-in" (without legal sanction as in Bogota and Athens) to the regular municipal system.

Case (7): Decentralized, Self-Help Solutions at the Household Level

Solution of the problems of infrastrucure at the household level in squatter areas has not been well documented. However, one can imagine that such individual solutions might range from carrying water in and waste out using buckets, to the use of a recycling appliance to purify the household's wastewater for re-use as described by Richard Bender.[16] The former is the type of solution that individual households now resort to in unserviced areas. The latters is a presently high cost, high technology solution that has been developed for use in spacecraft and pleasure boats; it might well be further developed for widespread inexpensive use, recirculating perhaps a finite body of water stored in a roof tank -- topped off occasionally for losses from evaporation, etc.

Each of these individual solutions has the advantage of improving the conditions within an individual household. However, eacH has the disadvantage of only improving the environment of the settlement when it is employed by a majority of the households. (These advantages and disadvantages will be further discussed later.)

PRACTICAL ARGUMENTS FOR SELF-HELP

Most efforts to service squatter settlements have involved the extension of standard water and sewer networks; but these efforts have been extremely limited, reaching only a tiny fraction of squatter populations. There is virtually no hope of extending to provide service for all urban residents, using these methods. We suggest that the only possible way to reach this goal is to expand the use of self-help methods, allowing individuals and small collectivities to upgrade the environmental quality of the areas in which they live.

However, there are three major arguments against this proposition:

First, that the environment is intrinsically shared, leading to the traditional view of water and sewer systems as collective goods. IN other words, even if an individual household or group of households use self-help

16 Bender, Richard. "Incremental Infrastructure", University of California, Berkeley, California, 1974.

methods to improve their own living conditions, the surrounding environment will not be improved until the remaining households in the community also participate in the program.

It is obviously true that the environment is shared and that in order to resolve the external environmental problems self-help solutions must be coordinated for an entire community. However, it can be argued that even where this level of organization has not been achieved the individual household may improve its internal conditions using self-help methods, for example carrying in bottled water and fuel, carrying out human wastes, digging ditches around the dwelling to divert wastes draining from other households, etc. While these activities may not siginificantly improve the total environment they can make an important difference in the household's own health and living conditions while not precluding later community or municipal solutions.

However, it can be argued that the total environment is not the responsibility of the individual squatter household, but must be addressed by a body with broader responsibility, such as the municipal government. The responsibility of the squatters is first to survive -- to improve living conditions for themselves and their children. If self-help activity can accomplish this it should be encouraged.

The second argument is that economies of scale which are achieved by large, centralized systems are lost to self-help systems. Proponents of these objections demonstrate that the unit-cost or cost-per-household is substantially less for large-scale centralized water and sewer systems than for thousands or hundreds of thousands of individual households or small groups, attempting to somehow provide their own serivce. Given the present water/waste technology, the basic thrust of this argument is indisputable. However, we do dispute: 1) the alleged magnitude of the disparity between centralized and decentralized systems, and 2) the assumption that the cheapest way to extend infrastructure to unserviced households is the best way. This assumption is based on the apparently plausible argument that the less expensive the cost per household, the more likely the service will be provided. The problem, of course, is that these "less expensive" options have been available for generations, but not exercised. Thus, again, the theme of this paper: How to change this record of enormous public default.

Another simple observation strikes at the heart of this "least cost" argument. In the area of electric power, for example, small scale production of electricity is typically measured against central station rates of only a few cents per kilowatt hour (kwh). If a small scale generator can begin to approach those costs it is viewed as promising; if not, it is labeled impractical. Such analysis is wrong, for it assumes availability of central station generators and distribution grids to all areas. In fact, very poor people often willingly pay several dollars per kwh when they buy batteries for transistor radios. Most simple unit-cost comparisons assume availability in this way; and, in addition, disregard the form and quantity of ultimate use of the service and its importance to the consumer.[17] Experts in the area of water/waste typically start with the unit-cost argument, demonstrate the obvious cost advantage of large scale over small scale systems, and rest their case. The result is obvious: millions of households with no central service nor any hope of it in the future and no alternative.

Second, unit-cost comparisons between large, centralized water/waste systems and decentralized small scale systems at present compare fledgling and rather esoteric small-scale technology (to which mass production techniques have hardly yet begun to be applied), to the well established technology used in centralized systems. For example, the physical-chemical water/waste recirculating principles applied to spacecraft, pleasure craft, submarines and even some small communities, plus some of the newer filtering techniques are

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17 Merriam, Marshal F., "Decentralizing Power Sources for Developing Countries" University of California, Berkeley, California. 1972.

widely known,[18] but have yet to be mass manufactured for use by households or small communities to continuously recycle and re-use a finite supply of water. Until very substantial applied research is directed toward this end, unit-cost comparisons between centralized and decentralized systems will continue to appear highly disparate.

The third argument against self-help provision of infrastructure is based on the demands of the existing technology. It is argued that the level of capital necessary to install infrastructure makes such an enterprise impossible for squatters. In addition, the difficult topography and dense residence patterns make installation of traditional water/waste grid nearly impossible even with the use of heavy equipment. Thus, self-help installation is certainly prohibited.

This argument is illustrative of the trap into which infrastructural planning has traditionally fallen. Thinking of the problem only in terms of the standard solution of rigid pipelines and collection networks imposes assumptions about requirements of capital, organization, and topography which are not inherent in the problem. A range of decentralized solutions, both traditional labor intensive and high technology capital intensive, now exist which lend themselves to implementation using self-help methods.

Besides rebutting the common arguments against self-help, a number of positive arguments, illustrating the limitations of the present technology, can be made to support the use of self-help. These arguments fall into three categories:

First, arguments based on the record of systematic failure and default by centralized entities in the face of increasing need and desperation on the part of unserviced squatter areas. It is self evident from the examples discussed earlier that it is not viable to expect governments to amass the

18 Bender, op.cit.

resources and commitment to service squatter areas in the near future. If squatters are to receive services in most cases it will be as the result of their own initiative.

Second is the argument of the prisoner's dilemma. In the traditional system of infrastructure provision it is difficult for an individual household to see the results of any input or sacrifice it makes for the good of the whole. That action may be one among thousands and make little difference in the total condition. In a self-help situation, on the other hand, the individual is able to see direct results of his or her contribution to the community good because of the smaller scale and the more direct control.

One cannot ignore this crucial need and desire for personal control over facilities and service directly related to survival. For example, one could conceivably show substantial unit-cost economies if all households consented to centralized cold storage lockers and warehouses for food, as opposed to individual home refrigerators. However, the loss of personal control and access convenience would be generally considered unacceptable in the case of one's food, but is virtually taken for granted in the case of one's water supply. (It might be noted that many squatter households, even in the poorest and most austere circumstances, have refrigerators. They are relatively inexpensive, often being locally rebuilt discards of the rich, the electric energy is virtually free, being "pirated" from central transmission lines, and they are a vital aid in the squatters' battle against hunger.)

Third, and perhaps most important in our attempt to rebut the "least cost" argument in support of the traditional water/waste technologies is the fact that these systems often involve substantial hidden diseconomies. When these diseconomies are made explicit, the advantages which the centralized systems appear to have over alternative decentralized systems become less significant, particularly advantages of economies of scale. The hidden diseconomies of the present technology include:

1) Excessively High Standards

At present, most centralized systems purify all water to standards of human consumption, although only a small fraction is actually used that way. The remainder is utilized for other household uses, such as cleaning, laundry, bathing, animal consumption, etc., requiring lower levels of purity. The relatively unexplored question is: If an individual household purifier could be regulated to produce water only to the degree of purity needed, thereby purifying the majority to less than potability, how much of the unit-cost could be saved?

Most cost comparisons ignore this possibility, assuming the individual purifier must produce all output to drinking standards. Phrased another way, how much more coverage might existing municipal systems achieve for the same cost if the 100% potable standards were relaxed? Many primate cities in developing countries now service half to two-thirds of their populations with potable water and the remainder with nothing. The ability to trade-off greater coverage for potability at the same cost seems rarely, if ever, to have been broached. The ability of individuals to boil, filter, or otherwise purify a fraction of semi-potable water to bring it up to drinking standard has received little attention. Combinations of central service and an individual purifying applicance offer an area of unexploited potential.

2) High Cost of Service Transport

A second hidden diseconomy inherent in the conventional water/waste technology is the high cost of transport. It is estimated that fully half the cost of conventional systems is the pipeline network connecting points of service to the central facility. Purifying appliances and recycling units for small clusters or communities could substantially reduce the cost of pipeline connections and individual household purifiers and recycling units could virtually eliminate pipe costs altogether.

Thus, in comparing per-unit costs of a decentralized system to those of a centralized system, the extra costs of the individual purifying unit are mitigated by the saving in pipeline costs. As noted this saving could be up to 50% of the cost of the entire centralized system.

3) The Costs of Obsolescence

Related to the consideration above are the costs of obsolescence. In Seoul Korea for example, twice as much water is purified as is used. As noted earlier, half of the pure water leaks out of an obsolete pipeline system before it reaches users. To repair and replace the pipe network (built around 1900) would be so costly and difficult that the city prefers to purify more than an extra half million tons of water daily at significant wasted cost and water. Again, this kind of wasted or extra cost should be included in the comparative cost analysis of centralized and decentralized systems, and may significantly offset centralized economies of scale.

4) The Problem of Large Increments

Economies achieved by large scale systems may also be offset by the problem of large increments. For example, capacity additions to a metropolitan water/waste system are typically measured in increments of thousands or tens of thousands of new users. Yet obviously demand usually grows more smoothly. Thus, there is often a substantial disparity between capacity which grows as a step function and demand which grows as a relatively smooth function (see Figure 2). The result of this disparity is necessarily a condition of overcapacity and/or undercapacity -- both of which represent diseconomies as shown in the Figure.

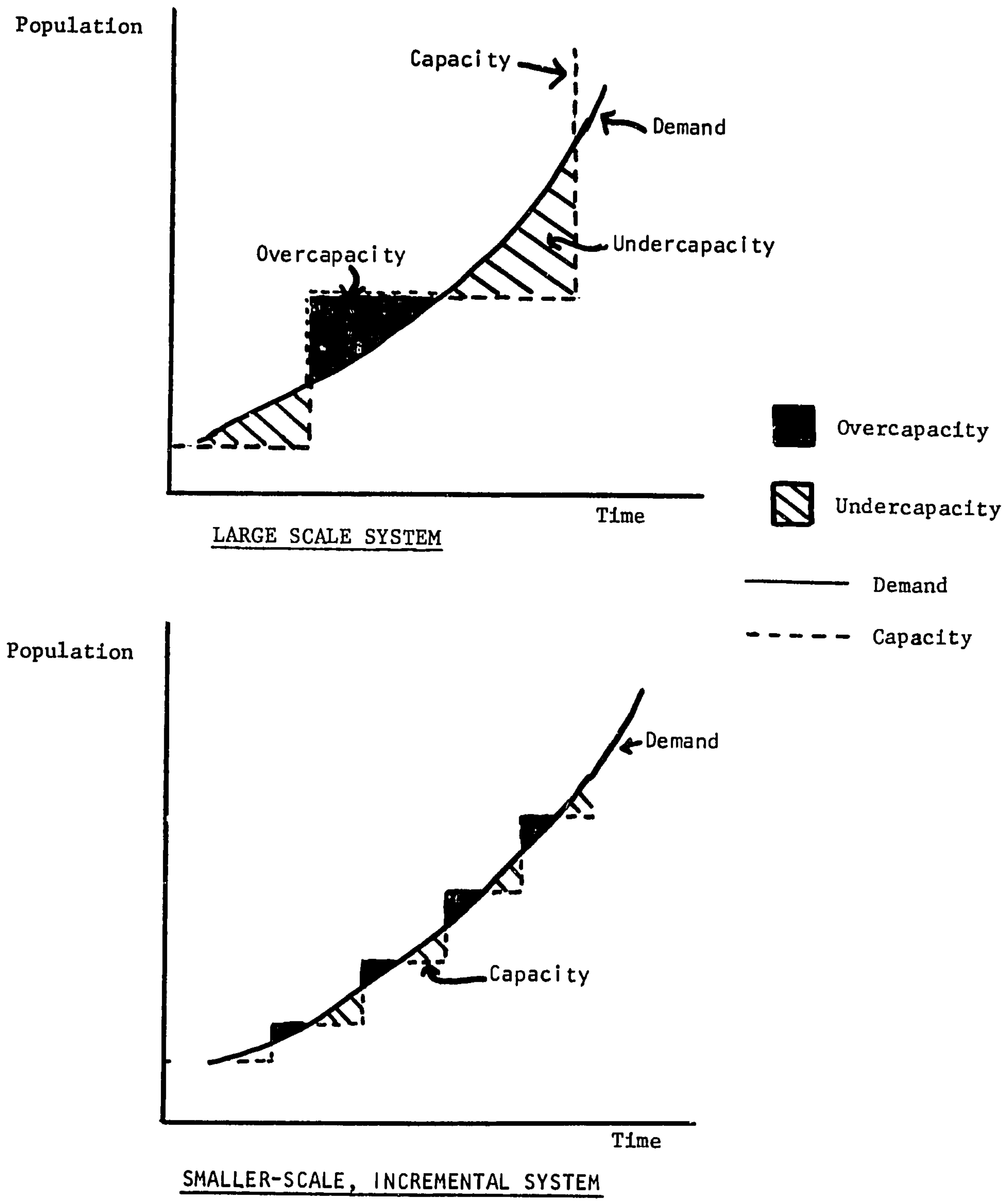

FIGURE 2: PROVISION OF INFRASTRUCTURE - LARGE SCALE VS. INCREMENTAL SYSTEMS

The cost of overcapacity in the U. S. has been estimated by Richard Weinstein[19] to be 23% for capital costs and 15% for operating costs. These are costs which would not accrue to a system which could grow in small increments, closely keeping pace with demand.

Whereas the monetary costs of overcapacity can be computed fairly directly (as for the U. S.) the costs of undercapacity are usually imputed and therefore only crudely estimated. However, the world-wide consequences of undercapacity as expressed in terms of pollution, human suffering, disease and death virtually defy monetary translations, but are obviously enormous. While the adoption of small-scale incrementally expandable infrastructure would not directly address the latter problem it could substantially reduce the former, and again, this must somehow be considered in comparative unit cost calculations between large and small scale systems.

A corollary to the problem of large increments is that of investment inertia, particularly in developing countries. Because the capital required for substantial upgrading or expansion of a system is enormous, the work is often postponed or delayed in favor of smaller, more manageable investments. The example of Seoul's outdate pipe system cited above is a dramatic example of investment inertia. To dig up, replace, repair, and upgrade Seoul's pipeline network would be so costly that the investment has been repeatedly postponed.

The universally difficult decision as to when, where, and how much to invest in infrastructure is further complicated by investment lag times, forecasting uncertainties, etc. These difficulties grow with the size of the system and add to the problems of trying to meet repeated small demand increases with large capacity increments.

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[19] Weinstein, Richard. "Water Recycling for Domestic Use", Astronautics and Aeronautics. Volume 10, Number 3. March 1972

5) The Costs of Installation of Rigid Networks

The conventional water/waste technology is characterized by a hierarchical grid of rigid pipe. The imposition of such a grid on the often chaotically packed pattern of settlement in squatter areas implies destruction of approximately one-fourth or more of all dwellings. If compensation is offered, the procedure becomes extremely costly. However, even if it is not offered, destruction and dislocation at this scale would most likely be considered to be politically and socially unacceptable. This problem also would be greatly mitigated by small scale, flexible systems, or individual purifying appliances, and the costs of relocation compensation, or the imputed costs of dislocation, must again enter comparative calculations as a relative benefit of small scale systems.

6) The Extra Costs of Servicing Marginal Land

The marginal land upon which most squatter communities have been forced to develop (available only because standard settlement has bypassed the land as unbuildable or undesirable due to conditions of steep slope, poor drainage, long distance from the city, etc.) implies exceptionally high costs for the installation of underground mains and pipelines. In most cases the extra costs of extending pipes, buildings pumping stations, etc. simply reinforce governmental inaction. Once again, in considering water/waste service to these areas, hidden diseconomies inherent in the conventional technology yield a comparative advantage to individual or small scale alternatives with reduced amounts of pipe. Any extra cost involved in extending conventional technology must be considered as available to offset apparent cost disadvantages of smaller scale, flexible, self-contained technologies.

7) Failure to Tap Unused Resources with Shadow Prices near Zero

Large, centrally provided utility systems, with rare exceptions have been unable to tap into the substantial pools of under- and unemployed labor of developing countries, because to do so usually require far more organization and social discipline than is available. This labor pool is and can be enormously systems have not been able to tap into the substantial pools of under- and unemployed labor of developing countries. The reason is that to do requires far more organization and social discipline than is generally available. That this labor pool is and can be enormously productive, ingenious, and resourceful as is manifest in the world's millions of squatter homes built largely outside the monetary exchange system with self-help, bartered, or exchanged labor. Only a few exceptional societies have been able to tap this resource for large scale public works -- most notably China which has overcome much of the prisoners' dilemma through heavy social and political indoctrination and discipline. As noted earlier, however, the prisoners' dilemma is reduced as the size of the collectivity is reduced. At the household level, it is virtually absent; thus household-sized efforts can command the easiest and most enthusiastic participation. Whereas laborers usually must be paid for participation in a large collective effort, they willingly volunteer effort where it can be seen to be of direct personal benefit. A technology, therefore, which is individual, can capture non-market self-help labor much more easily and with much less discipline and indoctrination than a large collective system. The degree to which this will save costs, depends of course, on the labor intensity and skill level required for the particular technology in question. Nonetheless, this is an inherent advantage of smaller systems which helps to offset the potential economies of scale of a larger system.

In short, there are numerous hidden diseconomies inherent in the presently used large-scale technology. Among them are: excessively high standards, the high cost of transport, the costs of obsolescence, the problem of large increments, the costs of rigid networks, the problem of marginal land, and the failure to tap unused resources. All these combine to mitigate the economy of scale advantages attributed to large scale systems, but are rarely taken into account in typical cost-per-unit comparisions. The point of this section is that if these diseconomies are taken into account, more budgetary latitude might be given to the development of small-scale or individual systems.

IDEOLOGICAL JUSTIFICATION OF SELF-HELP

It is unlikely, based on experience, that centralized government assistance will be forthcoming at a scale sufficient to solve the problem. In this situation of central government default, the option of self-help solutions must be considered. However, consideration of self-help raises ideological as well as practical issues.

It has been suggested that self-help is a reactionary mechanism used to co-opt residents of squatter areas, easing their plight sufficiently to relieve pressure on the government, at greater expense to the squatters than to the government; rather than a constructive means by which squatters may survive, improve their situation, and at the same time gain greater control over their environment, including developing power and organization to apply pressure to the government.

In fact, both statements reflect reality. The first result is an unintended, but not unanticipated byproduct of the second. To accept the value of self-help it is necessary to accept that the possible byproduct of co-option may be necessary in order to achieve the higher priority of survival. Revolution is an activity of the upwardly mobile; of people who have moved beyond subsistence living. Many squatter households are still struggling to achieve subsistence.

If, following this line of argument, the issue is defined as one of community survival, it is frivolous to discuss whether that survival should be allowed or disallowed, on the basis of the political goals of other groups. From the squatters' perspective the provision of water and sewer facilities (and in some cases transportation) is critical to the survival and health of the community. If the central government is willing to provide these services this solution is obviously acceptable. Perhaps organized pressure on the government will provide such a solution. If not, we are suggesting that self-help solutions must be considered. The choice for the squatter community is not between centralized and self-help solutions. That choice has already been made by the government. The squatter community's choice in such a default situation is between self-help and disease or worse.

Self-help may also be justified on positive grounds. It can provide important advantages in control over resources, lack of dependence on technology controlled from the outside, lack of dependence on central authority and its biases and whims. If successful, self help efforts can provide the impetus for further organization stimulating the next level of improvement of the community and perhaps developing a level of political awareness not previously present.

POLICY IMPLICATIONS OF SELF-HELP

The experiences cited above indicate that self-help solutions should be considered at two quite different scales and levels of decision making. The first has already been mentioned -- the squatter community in a situation of government default. In such a situation where the government is clearly unwilling or unable to respond to the need for infrastructure, the community may adopt self-help methods to alleviate the worst problems. Without the administrative and technological support of the government (or some other outside group) the efforts of the squatters will be small scale, of limited effectiveness in resolving external environmental impacts, and frequently provide lower quality, less effective infrastructure than that provided by the regular system. Some of these disadvantages could be neutralized by the development of more flexible technologies for the incremental provision of infrastructure. Others are inherent in the lack of centralized planning. Self-help solutions should be considered by squatter communities since they have the capability to significantly improve internal conditions. However we should recognize that the scattered efforts of individual squatter communities will not significantly diminish the infrastructure problem at the municipal or national scale.

This is the second level at which self-help solutions should be considered. Where it is impossible for the central government to extend the regular system of infrastructure to squatter areas due to lack of resources or commitment, the model of centralized initiative and technical assistance combined with self-help labor and implementation should be seriously considered.

The most successful examples of self-help conform to this model. From the perspective of the government this model provides an inexpensive, labor intensive solution to the vast array of infrastructure needs of rapidly growing squatter areas. The limited resources of government may be spread further, providing a comprehensive approach to municipal needs rather than expansion of the standard infrastructure to only one or two "pilot" areas. This approach also allows servicing of areas whose density or topography makes use of traditional utility grids and pipe networks impossible. It may be possible to install more flexible systems in these areas to provide adequate, although perhaps lower quality, service. These systems may be permanently autonomous, or may be connected with the external municipal system at a later date if desired.

Centrally coordinated self-help solutions can capture some economies of scale--for example research and development of new technologies and dissemination of this information, purchase of heavy machinery which can be moved from one area to another to aid self-help efforts, coordination of individual solutions, linking self-help systems to an external municipal system and thus limiting the external disadvantages of self-help solutions. At the same time the dependence on local self-help implementation allows some control over infrastructural installation.

Although in the past this model of centrally coordinated self-help has been identified with socialist economies and governments, there is no reason why governments less inclined to spend resources on the welfare of low income communities could not be persuaded of the advantages of such an approach. Elements of this solution which should be stressed to such a government are the low level of capital required and the potential for solving the massive problem of infrastructural needs with minimum government effort. Although we believe that the common assertion that self-help diffuses .. potential for revolution in squatter areas has been refuted,[20] this fear should be exploited where it appears to be an effective tactic.

The economic benefits of decentralized infrastructure technologies should also be considered in setting government policy, for example, the development of decentralized "cottage" industries to supply the private market with the necessary component products to meet the incremental demand of households and communities developing infrastructure. This would provide employment for unemployed and underemployed urban populations, diversifty local and national ecnomies, and obviate the necessity for large scale investment in foreign products -- thus helping national trade balances.

TECHNOLOGICAL ALTERNATIVES

Regardless of the point on the centralized-decentralized spectrum at which the response is made a choice must be made between different technological means of providing infrastructure. To choose the appropriate technology it is necessary to understand the potential of developing and recently developed technologies, to have a clear sense of the alternatives and to develop strategies for implementation.

Self-help provision of infrastructure by households or small collectivities forces one to abandon the traditional concept of infrastructure provision by capital intensive installation of rigid pipe networks and to begin to consider more flexible decentralized alternative technologies. Some of these "alternative technologies" do not represent significant technological innovation or even use of sophisticated hardware; rather they may include new concepts of organization applied to indigenous methods of dealing with water/waste needs. Frequently in the rush to imitate infrastructure systems of the cities

[20] see, for example, Janice Perlman, The Myth of Marginality: A Study of the Favela Areas of Rio de Janiero, unpublished Doctoral Dissertation, MIT Department of Political Science, Cambridge, Mass. 1972.

of Europe and North America developing nations have discarded systems much better suited to their needs rather than attempting to adapt these indigenous systems to the requirements of rapid urbanization.

The technology available for implementation on a decentralized basis ranges, as is suggested above, from capital intensive, highly sophisticated "black box" solutions which allow a household or community to continuously recycle its water to labor intensive indigenous solutions most clearly represented by the hand-carried bucket. THis technological range is discussed below for the areas of water and waste. It should be noted that the same range exists for other types of infrastructure.

The range of technology for <u>water supply</u> begins with the most simple solution which is simply a bucket which may be used to carry water from the nearest stream. Fresh water is carried daily to provide for the needs of the household. This requires no skill and no capital investment. If water is provided by a municipal water system or wells the bucket may also be used to bring water to the household from these sources.

Depending on the availability and purity of ground water, a well may be sunk within a squatter settlement to provide water for the surrounding households. However the density of settlement and pollution of the groundwater by untreated sewage frequently eliminates this solution.

Another possible means of water supply is the delivery of water by truck, handcart, mule-drawn cart, bicycle, etc. This may include bottled water for drinking, or larger quantities of pure or semi-pure water for household use. The latter system may employ large tank trucks to deliver water to individual household tanks or to larger community tanks. Water may be drawn from community tanks by bucket as described earlier, or may be piped from the community tank to the individual households by a simple dispersal network. In the case of the dispersal network it would be possible to connect the community network into the municipal system at a later date. Meanwhile the need for dependence on the central network and the capital required to lay pipes connecting with the municipal system are not required.

Technology also allows cost reduction in any of these systems by allowing water to remain semi-potable, purifying only that water which will be consumed by humans. One such process is an inexpensive water-purifying device which may be attached to a faucet to purify the water passing through to obtain potable water. The device is manufactured in a hand-held model activated by a syringe-like pump to draw water from streams or other bodies of water. Such a device costs about $12, a larger variety about $35 Tests conducted in Germany and Switzerland have certified that this "Filopure" device impedes the passage of microbes and bacteria, eliminates unpleasant tasts and produces completely pure water.[21]

At the capital intensive end of the range of solutions is a "black box" appliance which recycles sanitary waste to produce water, methane fuel (which will provide energy to run the appliance), and a small amount of waste which may be periodically collected. This solution allows the unit , whether it is a household or community, to be virtually self-sufficient for sanitary functions. Such techniques are currently in use in developed nations, particularly in the recreation industry -- individual units are utilized in mobile homes, pleasure craft, and vacation homes. Submarines and space vehicles provide other highly visible examples of high technology recycling systems.

At a large scale, "black box" technologies are now being used at the community level in residential complexes in New Jersey and California to recycle the waste water for reuse.[22]

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21 C. Conrad Manley, "No Water too Foul for Swiss Filter Device," Christian Science Monitor, April 3, 1974.

22 See for example, "A Totally New Method of Sewage Treatment", House and Home, McGraw Hill, New York, New York, 1972.

The simplest solution to the problem of waste disposal is the construction of a latrine pit. This is an adequate method until settlement density results in significant pollution of the water supply and insufficient land to move the latrine at frequent intervals. This traditional method could be extended to a system of latrine pits emptying into a buried concrete trunk. At one end of the row of pits a water tank would periodically discharge water to carry away the wastes into a septic tank at the other end of the row.[23]

Another possible solution is the chemical toilet. This provides the advantage of decentralization, however it must be periodically resupplied with chemicals and, being radically different from the familiar methods, may be difficult to implement.

The equivalent of water techniques exist in this area in the use of buckets to remove waste - either at the level of the individual household for use as fertilizer, or at the community level by a collection system. Waste disposal may also include use of tank trucks for removal of wastes from a community holding tank. As with the water supply, this allows later connection with municipal sewer systems should this appear desirable.

The capital intensive end of the range of waste technology solutions is also the black box, as previously described. Richard Bender has suggested that an advantage of the community water tank/waste holding tank system is that as the "black box" technology becomes more available to low income communities in developing countries "black boxes" may be installed in each community to replace the water and septic tank, allowing the community to recycle its water and eliminating the need for water provision and waste removal by tanker truck - the same distribution and collection system may be used within the community for either technology.[24]

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23 Jerome, op. cit.

24 Bender, op. cit.

ELEMENTS OF TECHNOLOGY CHOICE

The actual choice of technology is a complex process, based on consideration of diverse factors in the context of the specific requirements of the situation in question. In considering these factors it is necessary to understand the level of capital expenditure which will be required and operating costs which may be expected over time. The factors which must be considered in the choice of technology are discussed briefly below and displayed in Figure 3.

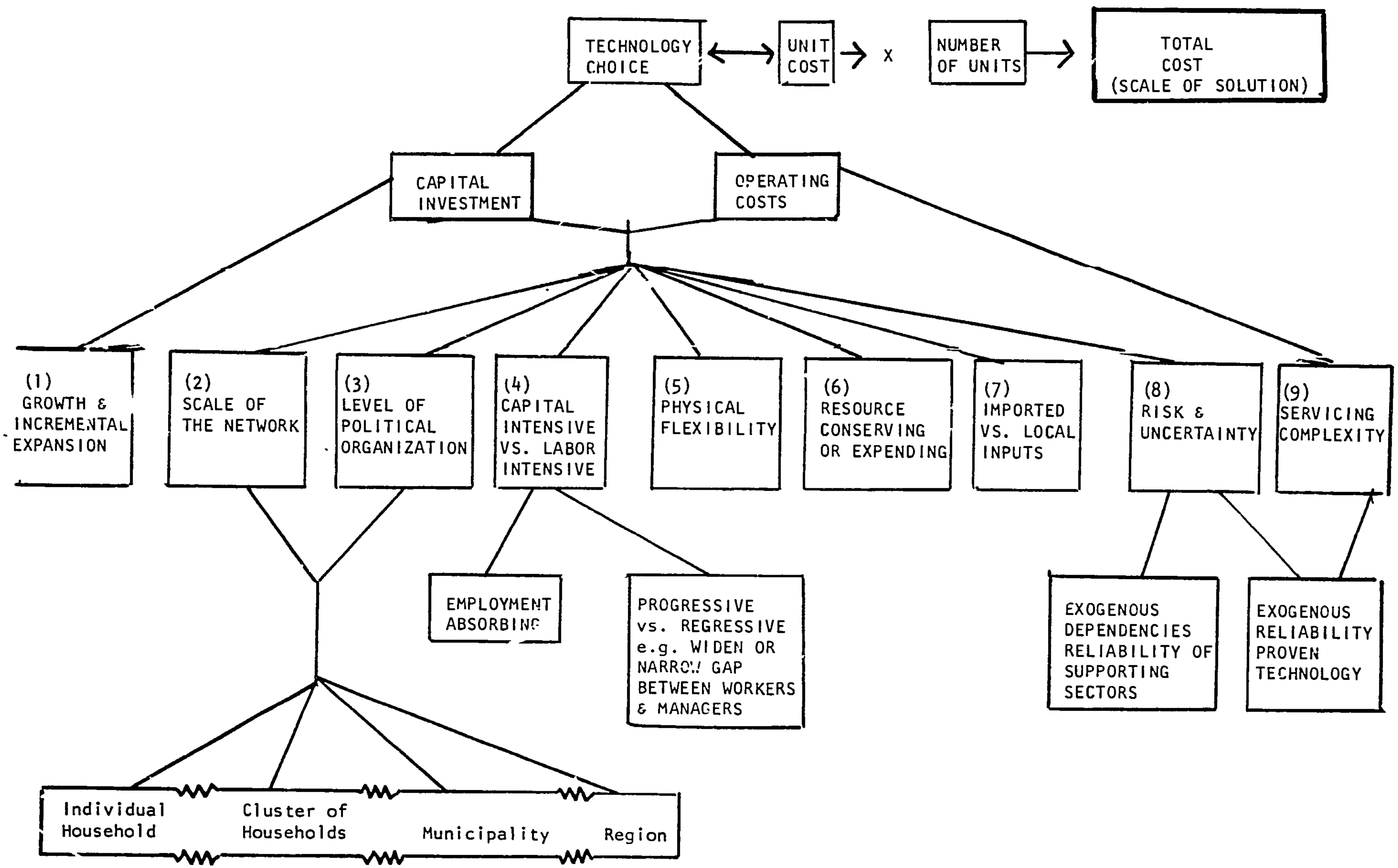
(1) Growth. Does the technology enable the incremental growth and expansion of the infrastructure as the community grows, avoiding the problems of over- and under-capacity previously discussed?

(2) Scale of the Network. Is the operating scale of the technology appropriate to the needs of the situation? For example the needs of the individual household may be met with a different technological mix than those of the community.

(3) Level of Political Organization. This issue is closely related to the scale of the network -- in order to develop a solution at a scale larger than the individual household some level of political organization and mutual cooperation is necessary. If the community is not socially and politically organized it may be necessary to choose a technology where each household is able to operate relatively independently of the decisions of its neighbors.

(4) Capital Intensive vs. Labor Intensive. This is a critical issue for choice of technology for developing countries, may of which face labor surpluses and capital scarcities. This scarcity of capital has been an important factor in the lack of service provision to squatter communities. Even when a government has the will to provide infrastructure, if the only means of doing so is to import technology , the project can be prohibitive from a balance of payments point of view. In such a situation, local or labor intensive technologies should be considered, the latter having the advantage of being labor absortive as well.

FIGURE 3: TECHNOLOGY CHOICE



(5) Physical Flexibility. It is important to choose technology that is sufficiently flexible to be used on the marginal land on which squatter communities tend to be located. Ability to adapt to the difficult topography and dense settlement patterns without disrupting the existing settlement unduely is an important consideration in technology choice. Relatively small-scale water technology using hoses rather than pipes might be used. The added accessibility of such a technology can be demostrated by comparing the incidence of electrical systems (a flexible wire) to water systems (a rigid pipe) in squatter areas.

(6) Resource expending vs. resource conserving. This factor is less important from the perspective of the squatter than from that of the society as a whole, concerned with the long term balance and conservation of resources. An element of this factor might emphasize technologies employing solar energy. the single component of the earth's ecological system which is virtually unlimited. It is also important to consider whether the resources employed are renewable or non-renewable and the local availability of these resources. This might lead to greater use of traditional building and construction methods using bamboo, wood, adobe, etc., depending on local resources.

(7) Imported vs. Local Technology and Inputs. In choosing a technology it is critical to consider it in light of the traditional methods. This is important in terms of costs, dependence on foreign suppliers and technicians and willingness of the squatters to utilize the system. This relates directly to the use of local materials discussed above - again for reasons of cost, accessibility and ease of implementation of the technology.

(8) Risk and uncertainty. The dependence of the technology on outside actors -- either foreign governments and suppliers or the municipal or national government -- may be a critical factor in the ability of the squatters to control and fully utilize the infrastructure they develop. It is important to view these risk and uncertainty factors in terms of the squatters' outlook rather than using government standards of risk.

(9) Servicing and Maintenance Complexity. This relates closely to the previous factor, emphasizing the need for self-sustaining technology, that will not require frequent skilled maintenance or replacement of esoteric parts. This perhaps suggests the use of a proven technology; and may indicate choosing a technology as close as possible to traditional methods, employing a minimum of foreign expertise, investment, and parts.

In summary, the importance of flexibility of technology choice can not be overemphasized. There is no reason that simply because New York or London have centralized, capital intensive, water/waste networks these are the most appropriate technologies for Kuala Lumpur, Rio de Janiero, or Lagos - particularly in their squatter areas. It might even be argued that these technologies are no longer the most appropriate even for London and New York. A choice of technology must be made which is appropriate to the particular situation --in terms of finances, topography, climate, labor availability and other factors discussed above. These aspects of choice are critical.

Conclusions

Throughout this paper we have stressed the need to consider alternatives to the traditional, large scale, capital intensive centralized methods of providing infrastructure. We have specifically suggested that self-help techniques for decentralized infrastructure provision by an individual household or small collectivity must receive particular attention and that these methods seem to be especially appropriate for use in areas of spontaneous settlement, such as the squatter areas which surround most major cities of developing nations.

Experience has forced us to assume a lack of government commitment and investment in the provision of infrastructure for squatter areas. It is this situation of default, and the simultaneous success of self-help techniques in similar default situation, such as housing, that has led us to suggest the use of self-help techniques for infrastructure.

Use of self-help will make necessary the development and dissemination of incremental technolgies which will allow decentralized initiative and action by relatively small units and avoid the problems of large scale systems discussed earlier. This should include both capital and labor intensive methods and effort should be made to link the technology introduced to traditional skills and methods, to allow as high a level of self-sufficiency and control as possible to the squatters. Otherwise the default situation will persist.

It is important also to consider the positive aspects of self-help and the possibilities of its use in the context of a government committed to positive action. Examples of self-help efforts supported and coordinated by the central government should be identified and analyzed. This mix of self-help initiative and labor with central coordination appears to offer an important model for nations with scarce resources and tremendous infrastructural needs.

Throughout this process of planning and technology choice possible solutions must be continually reformulated in terms of the problems at hand rather than in terms of the conventional solutions, choosing from the range of possible solutions the mix which best fits the needs and resource of the particular situation.

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ROADS AND HIGHWAY TRANSPORTATION IN DEVELOPING COUNTRIES

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It is not our intention here to examine all problem areas relating to highway transportation in developing countries (DC's). Rather, we wish to draw attention to the special aspects of these problems in such countries as compared with industrialized nations. Neither is it our intention to make recommendations about what needs to be done and even less about the pertinent specifications and standards. However, we would like to encourage the reader to think about these problems, the directions to be taken and resources to be brought to bear in light of the obstacles at hand. Rather than proposing a manual in a field where numerous specialized works are already available, it is our desire to throw greater light on existing situations with emphasis on their advantages, drawbacks and implications for the future, based on some 20 years of experience, success and failure.

INTRODUCTION

Highway transportation in DC's has grown enormously since World War II. As simple proof, whereas in the U.S.A. the number of motor vehicles increased by a factor of 2.5 between 1949 and 1972, the comparable figure was 4.8 for Australia, 6.5 for Nigeria and even 10 for Uganda.

Beyond any doubt, the reason for this large-scale development has been that highway transportation is a preeminent tool for development in these countries. During the nineteenth century, the railroad was one of the major driving forces in development, and the first basic transportation framework in tropical countries was conceived along these lines during the early 1900s.

As soon as the internal-combustion engine was developed, however, the changeover to highway transportation began gradually and steadily. Today, in most nations throughout the world the railroad is primarily used for mass transportation. Highway transportation offers the major advantage of door-to-door service and consequently favors development in depth while the railroad promotes primarily development of a linear type. A similar drawback handicaps air transportation, which maintains contact with a country only at its landing points.

Later, we will return to these problems of development. In the meantime, however, we would like to concentrate on aspects specific to developing countries. It should be noted that the exact definition of the expression "developing countries" is open to discussion and that major structural differences are often to be found between them. Furthermore, it is always useful to describe these countries by such essential factors as population density, GNP and, perhaps more important, the growth rate of this GNP. Later we will see that certain of these factors depend on whether the country has already entered a phase of genuine economic takeoff.

I - VEHICLES AND TRAFFIC

An analysis of vehicle types in DC's reveals the importance of goods traffic compared with passenger traffic. Table 1 shows that, in these countries, the percentage of trucks is on the order of 30-40 percent, whereas in industrialized nations it is more like 15 percent. The predominance of trucks is especially noteworthy in countries still below the takeoff point. This factor is decisive in the choice of infrastructure which, contrary to industrialized nations, is not dictated by the needs of individual transportation and the desire to avoid traffic congestion with the exception of a very few major arteries near large cities and, naturally, within these cities. Hence, the needs of goods transportation will influence the design and construction of highway infrastructure far more than in industrialized nations.

TABLE 1

NUMBERS AND TYPES OF VEHICLES IN SELECTED COUNTRIES (1972)

Country	Vehicles with 4 or more wheels	Percentage of Trucks	Number of Vehicles	
			Per 1000 pop.	Per Km of roads
U.S.A.	113,832,082	17.4 %	551.5	18.7
SWEDEN	2,617,973	5.6 %	322.0	27.0
GERMANY	17,704,841	6.9 %	284.0	42.1
FRANCE	15,920,000	12.0 %	307.0	20.2
NORWAY	1,023,860	15.6%	259.0	14.0
AUSTRALIA	5,297,116	18.9 %	391.0 (1)	5.7 (1)
GREAT-BRITAIN	14,451,000	11.3 %	266.0	42.6
JAPAN	22,576,184	43.0 %	210.14	21.74
ARGENTINA	2,502,000	31.3 %	105.0	11.4
GABON	13,248	43.7 %	28.0	2.1
POLAND	990,392	29.5 %	29.8	3.3
CHILE	344,420	39.2 %	35.0	5.7
IVORY COAST	89,100	32.8 %	18.1 (2)	2.5 (2)
TUNISIA	122,578	34.1 %	22.8	6.7
MOROCCO	332,551	27.1 %	21.6	13.3
CAMEROON	37,442	34.3 %	5.1 (2)	0.67 (2)
KENYA	132,494	46.5 %	17.0	3.1
INDIA	1,192,977	29.0 %	1.94	I.06
NIGER	14,856	15.1 %	3.38	2.00
INDONESIA	434,873	30.1 %	4.90	5.90

Source : I R F - World Road Statistics 1968-1972.
(1) This figure refersto year 1971
(2) This figure refersto year 1970

The range of vehicles travelling the roads of developing countries is very wide. In general, these countries do not produce their own vehicles which, depending on the sphere of influence, are supplied by American, European and Japanese builders. As for trucks, the types also depend on local regulations, one of whose most important provisions is the limitation of axle loads to 8 to 13 tons. Vehicle overloading is a common occurence in these countries, and its consequences are far-reaching. As an example, in the Ivory Coast in 1965, 35 to 45 percent of all heavy vehicles were found to be overloaded as against 7 percent in France in 1964. It should also be noted that, during recent years, there has been a large increase in the number of multipurpose pickup-type and commercial vehicles with payloads of less than 3 tons useful in transporting both passengers and goods.

The figures in Table 1 apply to vehicles in service. It is more difficult to give a general idea of the composition of actual highway traffic. Numerous traffic counts have shown, nonetheless, that trucks are overrepresented with respect to their share of the vehicle fleet. As an example, a 1971 survey in Peru showed a highway traffic count of 58 percent trucks for only 34 percent of the total vehicle fleet. This is only normal considering that goods vehicles are used far more heavily than passenger vehicles.

As a general rule, traffic is much lighter than in industrialized nations. Whereas traffic counts on main roads -- with the exception of super-highways -- total several thousand vehicles daily in industrialized nations, in 1973 in Paraguay, as an example, only 100 kilometers of roads had traffic figures exceeding 1,000 vehicles per day. In 1965 in Cameroon, 450 kilometers of roads representing 65.5 percent of the total carried more than 600 vehicles per day, while 61 percent accounted for fewer than 100 vehicles. In a 1968 study in DC's under the auspices of UNESCO, the figures given for average traffic were 100 to 5,000 per day on main roads, 50 to 800 vehicles on secondary roads and fewer than 100 vehicles on feeder roads.

Whereas traffic may be light, growth rates are generally higher. In this respect, it is still necessary to distinguish between those countries having already reached the point of economic takeoff, where traffic growth rates easily exceed 10 percent annually, and the others, where these rates are still small, in the neighborhood of 6 to 10 percent. Economic takeoff always results in large traffic growth rates, and this fact is of prime importance in the design of road systems. Depending on the case, the observed growth in traffic applies to trucks and private cars to varying degrees but, in all cases, to light trucks of average size.

As has already been seen, these light traffic conditions mean few if any problems with traffic congestion, resulting in substantial differences in the design of road systems.

Lastly, travel can be said to be characterized by a certain degree of precariousness and discomfort which worsen when the roads are of poor quality. In some areas, roads open to traffic year-round are to be found next to so-called seasonal roads only open to all or some vehicles -- usually heavy vehicles -- during dry weather. In many countries, legislation limits road use during the rainy seasons primarily to protect the roads from damage. River crossings and points of natural water runoff may also have to be closed to traffic during peak floods with rare return periods which the structures are too small to handle. Other natural phenomena, such as sandstorms, can also close roads to traffic. Lastly, generally speaking roads are more sensitive to bad weather because of their recent construction and because the landscape's natural state of equilibrium in terms of erosion has not been restored. Their susceptibility is also due to the low construction budgets generally employed.

II - ROADS

One of the characteristics of road systems in DC's is their low density. Table 2 shows road densities in a certain number of countries in relation to the country's area and population. As can be seen, densities five times less than those found in industrialized nations are commonplace.

TABLE 2

DATA ON SELECTED HIGHWAY SYSTEMS (1970 or 1971)

COUNTRY	Population (in millions)	GNP per capita (US$)	Length of road system (in Km)	System Density (Km per sq.Km)	Length of roads per capita (in m)	Percentage of paved roads
U.S.A.	199.0	5 051	5 971 160	0.64	30.0	44.0
SWEDEN	7.9	4 438	173 963	0.42	22.0	47.0
GERMANY	60.4	3 572	416 000	1.67	6.9	72.0
FRANCE	50.1	3 510	785 171	1.42	15.7	80.0
NORWAY	3.8	3 334	72 261	0.22	19.0	17.0
AUSTRALIA	11.9	2 870	903 139	0.12	76.6	44.0
GREAT BRITAIN	53.8	2 412	334 132	1.45	6.2	100.0
JAPAN	100.2	2 130	1 013 558	2.75	10.1	15.0
ARGENTINA	23.6	1 075	201 059	0.07	8.5	17.0
GABON	0.48	700	6 031	0 02	12.5	2.5
POLAND	32.3	650	307 810	0.98	9.5	50.0
CHILE	9.4	632	70 549	0.09	7.5	11.0
IVORY COAST	4.1	330	34 961	0.11	8.5	3.6
RHODESIA	4.9	320	78 470	0.19	15.8	10.0
TUNISIA	4.8	320	17 856	0.11	3.7	51.0
MOROCCO	14.6	270	24 775	0.06	17.0	85.0
CAMEROON	4.0	200	46 584	0.10	11.6	2.4
KENYA	9.6	160	41 467	0.07	4.3	6.2
INDIA	513.0	110	1 009 515	0.30	2.2	34.0
NIGER	3.8	100	6 943	0.006	18.2	7.0
INDONESIA	114.6	80	84 292	0.04	0.7	25.0

Source : I R F - World Road Statistics 1966-1970

It should be noted, however, that the figures in Table 2 should be viewed with considerable caution because, depending on the countries concerned, the indicated length of road systems may or may not include certain roads in lower categories, such as tertiary roads or farm-to-market roads. It also frequently happens that statistics cover only roads which are sufficiently developed to be taken into effective account in official highway department inventories.

The types of roads differ from those found in industrialized nations in four major respects.

a) Traffic

Road characteristics, including road geometry and type of pavement, generally correspond to traffic density albeit somewhat modest as we have already seen. These characteristics are not a function of transportation capacity but are rather arrived at in an effort to optimize transportation costs by including in this cost vehicle operating expenses and the cost of infrastructure construction and maintenance. Consequently, the technical level of service offered by roads in DC's is far below that found in industrialized nations. Furthermore, the rapid growth in traffic means that during their service life progressive stage improvements may be made to the roads to meet traffic needs ; thus, one of the major characteristics of roads in DC's is their evolution over time, which may be rapid.

b) Climate

Water is a major problem, considering that the DC's primarily have tropical and desert climates. In tropical areas, drainage problems must be solved to avoid the design of heavy, expensive roads and damage resulting from the insufficient bearing capacity of waterlogged subgrades. Here, systems offering protection against erosion are also of special importance. In desert climates, on the other hand, lighter pavements can be used ; however, the extraordinary floods of normally dry watercourses raise problems in the design of road structures.

c) Materials

Tropical regions are frequently lacking in good road-making materials. For years, lateritic materials were felt to be an asset in these regions. However, with the increase in traffic closer attention must be paid to their quality, meaning that a large part of these materials -- those of lower quality -- are now considered as unusable for road construction, or requiring strengthening through the addition, for example, of cement or lime. Nonetheless, the use of local materials for road construction is still necessary to avoid expensive construction costs. Their use creates a whole set of problems when little is known about their properties resulting in defective quality, local damage and even potential failure. Construction risks must be accepted, especially in areas where road systems are not highly developed, when justified by the related cost savings.

d) Limited financial resources

This factor is common to DC's . In particular, the shortage of foreign currency places a strong damper on the expansion of road systems and sometimes necessitates changes in construction methods, especially greater use of manual labor.

This shortage of resources also leads to the design of roads offering fewer user services than is generally the case in industrialized nations. This limitation, moreover, is fully justified in economic terms when traffic is light, since it is easy to show that in cost optimization the user's share of the total cost of transportation must increase as the number of users decreases. This reduction in user services includes the construction of rougher wearing courses (earth or gravel roads) and structures purposely underdesigned or submersible.

These considerations explain why these types of roads are encountered and lead to their classification as follows :

Paved roads

These are still few in number, relatively speaking, as can be seen in Table 2. In addition, some paved roads have but one lane. There exists a minimum asphalting level which is the volume of traffic beyond which the construction of a paved road is economically justified.

Clearly, this point varies as a function of local conditions and can range from 50 to 150 vehicles per day for a one-lane road to 100 to 300 vehicles for a two-lane road. Naturally, these figures must be viewed with caution, since they depend on vehicle operating costs, the construction and maintenance costs of various types of roads and on the already-existing condition of the road before it is paved.

Gravel roads

Construction of these roads, having a gravel surface, corresponds to an already advanced if not final state as far as the related earthworks and road structures are concerned.

Improved and unimproved roads

These roads are generally not built up and have poor geometry. They suffer from nonexistent or inadequate drainage and have no pavement or only scattered materials laid on the surface. Travel on such roads is precarious.

In general, road construction costs are rather high and in any case higher than in industrialized nations for the same quality. The main reasons are the scarcity of good materials, requiring trucking over long distances, and the high cost of imported equipment and products needed for road construction.

Table 3 shows some examples of construction costs, distributed between earthworks, pavement and drainage. It can be said that construction costs generally range between 40,000 and 140,000 US$ per km for surfaced roads and 20,000 to 100,000 US$ per km for unsurfaced roads.

III - MAINTENANCE AND STAGE CONSTRUCTION OF ROADS

High traffic growth rates and the dearth of financial resources mean that roads naturally acquire a highly evolutionary character. The basic method consists of opening many kilometers of light roads to traffic as early as possible while offering limited user services. Improvements are made subsequently to keep up with the growth in traffic. This approach is both logical and appealing. The 1950s and 1960s saw good use of this method, but various aspects were subject to criticism, as follows :

TABLE 3

ANALYSIS OF THE COST OF THE CONSTRUCTION FOR 8 ROADS IN TROPICAL AND SUB-TROPICAL CLIMATES

Costs in U S $ per Km (1966 - 1969)

Road	Principal Characteristics	Earth-works		Pavement		Drainage and small structures		Total cost
		Cost	%	Cost	%	Cost	%	
1	Micro-relief Formation width 8 m - Pavement 5.50 m Not surfaced	28 800	54	8 000	15	16 400	31	53 200
2	Micro-relief Formation width 8.30 m - Pavement 8.30 m Not surfaced	36 000	61	11 200	19	12 000	20	59 200
3	Micro-relief Formation width 12 m - Pavement 7 m Surfaced	78 000	48	58 000	36	25 200	16	161 200
4	Hilly Formation width 10 m - Pavement 6 m Surfaced	26 800	40	24 400	37	15 200	23	66 400
5	Flat Formation width 9 m - Pavement 7 m Not surfaced	6 000	22	20 800	75	1 200	3	28 000
6	Flat Formation width 9 m - Pavement 6.30 m Surfaced	7 600	25	19 200	62	4 000	13	30 800
7	Flat Formation width 8.50 m - Pavement 5.50 m Not surfaced	13 200	72	2 800	15	2 400	13	18 400
8	Medium Formation width 9 m - Pavement 7.50 m Not surfaced	25 200	52	13 600	28	9 600	20	48 400

Source : PIARC - Sixty years of PIARC (1909-1969)

- Users are unhappy with road quality during initial stages, and strong pressure has developed in favor of paved roads.

- Aid-giving organizations and donor countries are anxious to provide DC's with what can be considered a finished product.

- Lastly, stage construction implies thorough maintenance, since the road is opened to traffic at a time when it is particularly subject to damage. Lack of sustained upkeep leads to early damage, and a process of complete failure sets in far sooner than for roads completed from the outset.

These reasons militated strongly against the system of stage construction, and today the tendency is more and more towards the rapid construction of paved main road systems with traffic on the rest of the network handled as best as possible by rudimentary means with no intermediate types of roads. This tendency is unfortunate, in my opinion, because it departs from the optimum use of resources by failing to concentrate efforts where they are most productive. As an example, earth roads should not be viewed as a last-ditch solution but frequently the most suitable one for meeting the needs of the moment.

In any event, highway maintenance remains a difficult, worrisome problem. Few countries have the necessary maintenance services organized and equipped to keep their road systems in satisfactory condition. In fact, it is probably more a question of men than of financial resources. Men must be given proper training throughout the country even down to modest levels. They must also have a liking for continuous, repetitive work requiring a great deal of perseverance and viewed with less respect than construction jobs. It takes many years to develop maintenance services, and this is perhaps one of the most important problems encountered at the present time in developing nations.

IV - ORGANIZATION OF TRANSPORTATION

Two types of carriers are commonly found in developing nations. The first includes trucking companies having their own fleets of vehicles and a form of medium-term management. The second includes small operators and individual truckers who drive their own vehicles. They usually have no conception of their costs, and the rates they charge are primarily a function of existing conditions and personal needs. Furthermore, they generally attend personally to the commercial aspects of transportation. Consequently, in the absence of true overhead, their rates are low and often fail to provide major repairs and vehicle replacement. Installment-plan buying instituted by vehicle dealers has increased the number of such operators.

People have often wondered how small operators could survive in such countries. It has been said that, when one operator disappeared because his vehicle was worn out and he did not have the means to replace it, there was always another ready to step in hoping to do better. In actual fact, these small operators are replaced far less frequently than might be thought. A 10-year old survey in Senegal pointed out that 51 percent of the operators interviewed had been active for over 5 years. The fact is probably that these operators are engaged in other forms of business. They are certain to remain active, since transportation losses can be offset by earnings in other areas. The same survey also showed that, of the carriers interviewed, only 10 percent limited their activities to trucking, 60 percent were engaged in business and 30 percent were both carriers, businessmen and farmers.

The governments in question have taken steps to protect the profession where such structures have arisen by instituting transportation regulations. In general, these stipulate that certain types of freight, such as heavy goods trucked over long distances, must be handled by approved carriers, with provision for official rate structures in some cases. However, it is very difficult to enforce these regulations due to the lack of or powerlessness of inspection means. In addition, this type can have detrimental effects on the nation's economy. One such example can be found in Morocco where the regulations simply provided for preliminary approval limited to vehicles carrying payloads exceeding 5.5 tons. Table 4 shows the breakdown of goods traffic between different types of trucks in Morocco and Brazil. Local regulations can be seen to have stimulated the growth of transportation using light trucks to the detriment of average transportation costs.

TABLE 4

BREAKDOWN OF FREIGHT TRAFFIC BETWEEN VARIOUS TRUCK CATEGORIES

(in U.S. $)

Truck category (useful load)	Cost per ton/km	Country considered : MOROCCO		Country considered : BRAZIL	
		Category (1) percentage in tons/km	Component of average cost per ton/km	Category (1) percentage in tons/km	Component of average cost per ton/km
2 tons	0.032	16.0 %	0.0051	2.5 %	0.0008
3.5 tons	0.030	8.5 %	0.0025	5.0 %	0.0015
7 tons	0.022	40.0 %	0.0088	48.0 %	0.0105
10 tons & over	0.020	35.5 %	0.0070	44.5 %	0.0088
		100.0 %	0.0234	100.0 %	0.0216

(1) The percentages represent road count vehicles, and not the number of vehicles registered in motor vehicle departments. The percentages thus correspond to the number of tons of useful load, and obviously not to the number of registered vehicles.

Source : Informations et Documents BCEOM - n° 8 (1972) -

V - ROLE OF HIGHWAY TRANSPORTATION

Throughout the world, roads serve various functions commonly divided into three categories of road types.

International roads

These permit trade between neighboring countries and have led to major developments during recent years. Prime examples are the results obtained by the International Asian Highway with some 40,000 kilometers of roads, the Trans-Saharan Highway and the Trans-African Highway (see figure).

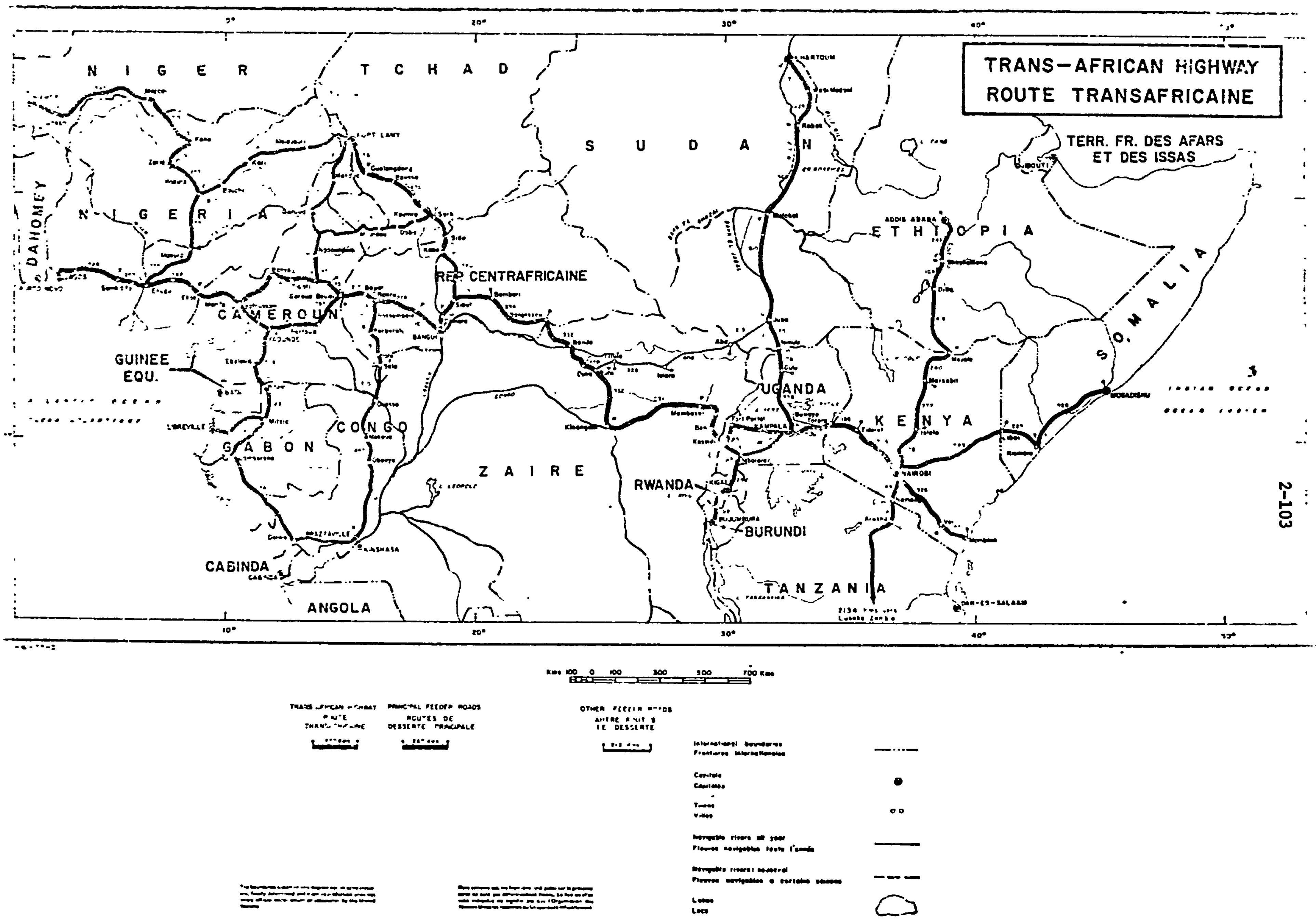
National roads

These permit trade between large cities in the same country. It is this type of road which has seen the fastest growth in developing nations since the end of World War II and until recent times. In general, the goal has been to provide the dependable transportation of goods and passengers, the exchange of ideas and information and a base for lines of command between large population centers of importance to the nation's life, including the capital, ports and administrative and business centers.

Local roads

These help integrate the local populations into the economic, administrative, cultural and political fabric of the nation. Undoubtedly , it is this function which has received the least attention in DC's. Much remains to be done in the construction of feeder roads. It is likely the greatest effort in years to come will be concentrated in this area.
This is a good time to note the effects of higway transportation in DC's and analyze the main factors involved :

a) The effects of higway transportation are tied to its cost. A reduction in costs, brought about by a change in infrastructure (in terms of construction, improvements and maintenance) or its regulation and organization, is felt directly by the user. In industrialized nations, the resulting benefits to present and future users are evaluated by standard techniques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REP CENTRAFRICAINE
CAMEROUN
SOMALIA
GUINEE EQU.
UGANDA
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CONGO
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BURUNDI
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ADDIS ABABA
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BRAZZAVILLE
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OTHER FEEDER ROADS
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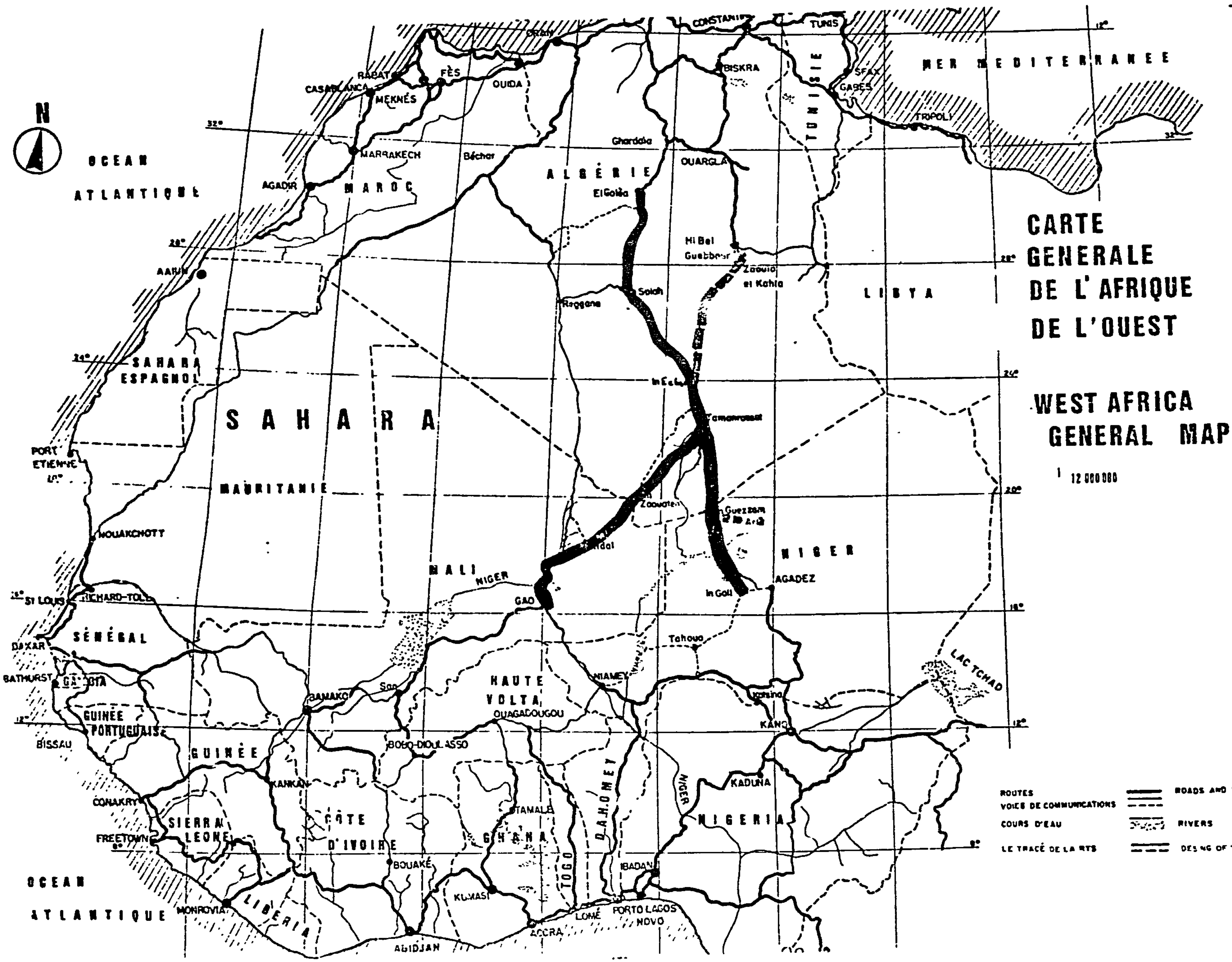
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LE TRACÉ DE LA RTS / DESIGN OF TSR

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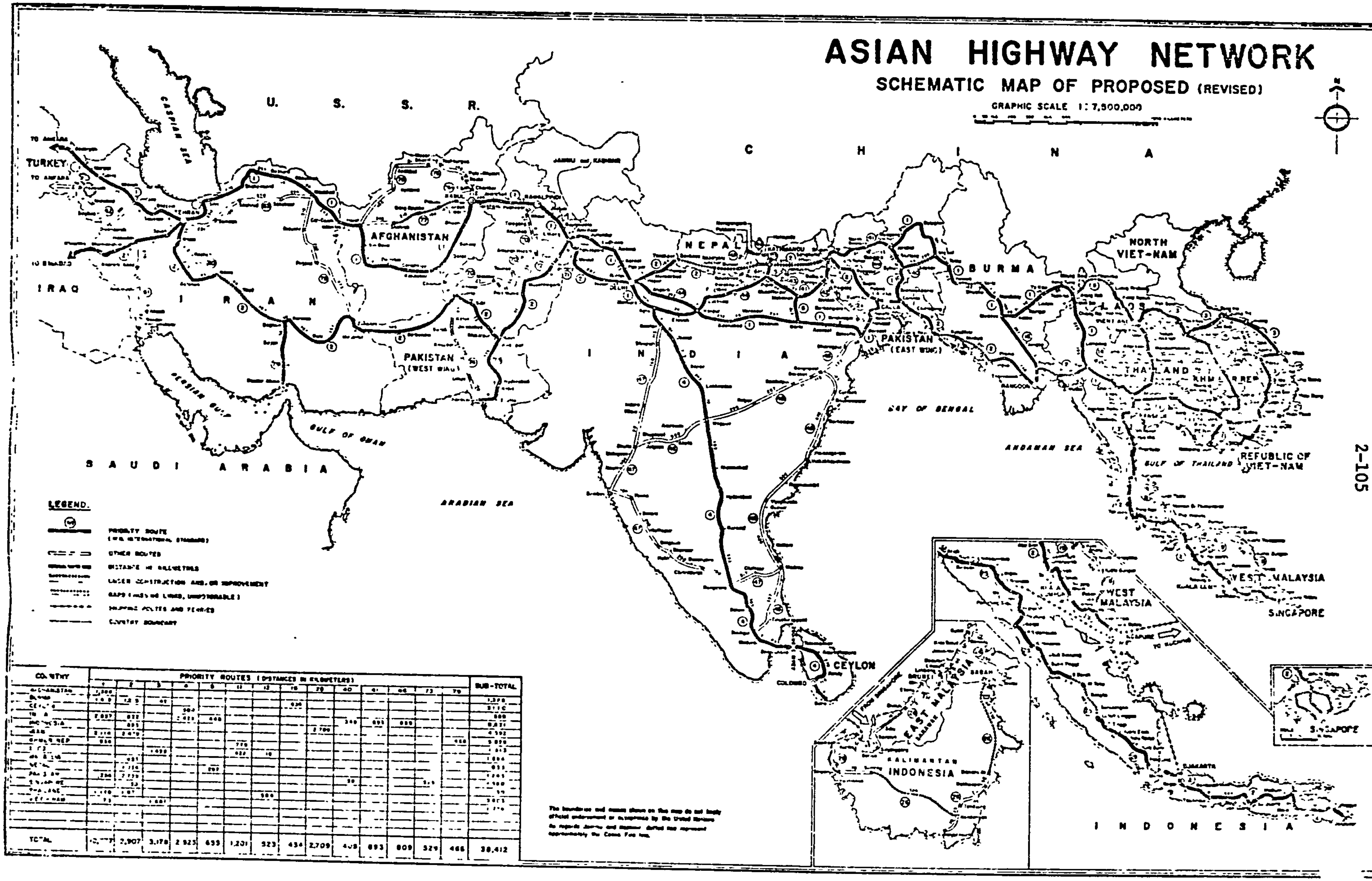


COUNTRY	PRIORITY ROUTES (DISTANCES IN KILOMETERS)														SUB-TOTAL
	1	2	3	4	5	11	12	16	20	40	41	66	73	79	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL	[illegible]	2,907	3,178	2,925	655	1,201	523	434	2,709	[illegible]	893	809	329	466	38,412

and include reduced vehicle operating costs, time savings and improved safety. This method is also used and found to be valid in DC's when relatively considerable traffic is already traveling on fairly sophisticated roads or road systems.
This is not the case of roads designed to provide entirely new forms of traffic.
It should be noted that, in general, vehicle operating costs and transportation costs in DC's are **substantially higher** than in industrialized nations. They also require large amounts of foreign exchange as can be seen in Tables 5 and 6.

b) Highway transportation and its improvement and expansion affect the GNP through reduced costs but also more directly through the opening up of new resources and the creation of added production capacity. This phenomenon is particularly striking when a new road is built in a region previously having no contact with the outside world. The availability of transportation stimulates production volume as an inverse function of transportation costs. Whereas a quantitative analysis of this phenomenon using the benefits to future users is theoretically valid, it encounters generally insurmountable obstacles. Foremost among these is the considerable uncertainty of traffic forecasts. In the DC's preference is given to a more direct approach devoted to forecasting production increases based on market behavior when trading possibilities are made available. Such behavior can only be analyzed on the basis of case studies in which changes in certain indicators are observed after a new road has been opened, for example.

c) Highway transportation and improvements have effects other than those which can be measured by an increase in the GNP. While contributing to the GNP, these have different aspects whose value must not be neglected by the various governments. These include the following :

TABLE 5

EXAMPLES OF VEHICLE OPERATING COSTS IN VARIOUS SUBSAHARAN COUNTRIES IN AFRICA AND IN MADAGASCAR

(In U.S. $)

COUNTRY & YEAR	VEHICLE TYPE	Operating Costs in Dollars per km			Corresponding average annual distance travelled (Km)		
		On paved roads	On laterite or rockfill roads	On trails	On paved roads	On laterite or rockfill roads	On trails
Cameroon 1965 (1)	10-ton Truck	0.28	0.42	0.54	40,000	40,000	30,000
	18-ton Unit	0.40	0.58	0.75	60,000	40,000	30,000
Niger 1968 (1)	Automobile	0.09	0.11	0.15	90,000	70,000	55,000
	7-ton Truck	0.18	0.24	0.38	80,000	60,000	45,000
	22-ton Unit	0.40	0.53	0.68	80,000	60,000	45,000
Madagascar 1968(2)	Automobile	0.08	0.09		12,000	12,000	-
	Pickup Truck	0.08	0.10		60,000	50,000	-
	Bush Taxi	0.11	0.15		50,000	40,000	-
	7.5-ton Truck	0.19	0.27		50,000	40,000	-
	19-ton Unit	0.33	0.48		50,000	40,000	-
Congo-Brazza 1969 (2)	Automobile	0.11	0.14		15,000	15,000	-
	Pickup Truck	0.12	0.16		50,000	40,000	-
	Bush Taxi	0.20	0.27		50,000	40,000	-
Chad 1969 (1)	12-ton Truck	0.32	0.48	0.72	80,000	50,000	25,000
	22-ton Unit	0.48	0.67	0.98	80,000	50,000	25,000
Zambia 1969 (1)	7-ton Truck	0.32	0.40	0.54	30,000	27,000	25,000
	14-ton Truck	0.38	0.48	0.69	58,000	55,000	48,000
	25-ton Unit	0.48	0.60	0.86	58,000	55,000	48,000

(1) The corresponding operating costs include the firms' overhead, business license, etc...
(2) The corresponding operating costs do not include the firms' overhead, business license, etc...

<u>Source</u> : Manuel sur les Routes dans les zones tropicales et désertiques - Tome 1 - Secrétariat d'Etat aux Affaires Etrangères chargé de la Coopération.

TABLE 6

STRUCTURE OF VEHICLE OPERATING COSTS IN VARIOUS COUNTRIES OF SUBSAHARAN AFRICA

(overhead, profits, excluding all direct taxes)

	Total Operating Costs	of which		
		Foreign Exchange	Taxes	Other local Costs
Automobiles and Pickups	100 %	25 to 35 %	15 to 25 %	45 to 55 %
Trucks and semi-trailers	100 %	30 to 45 %	10 to 20 %	40 to 55 %

Source : Manuel sur les Routes dans les zones tropicales et désertiques - Tome 1 - Secrétariat d'Etat aux Affaires Etrangères chargé de la Coopération.

Economic aspects

As an example, the effect on income distribution has a general economic aspect but also political and social aspects.

Social aspects

Examples are the effects on job distribution, the development of cultural activities, improvements in public health and the growth of education, the latter two equally contributing to long-term growth in the GNP.

Political aspects

Examples are the effects on population distribution, political unity and domestic security. In DC's, **expansion** of the road system broadens the influence and authority of the central government and integrates those people living in the area into the nation's policies.

Lastly, mention must be made of the structuring effect of highway transportation on development schemes. The shifting of villages, as is commonly observed in Africa where populations settle alongside the roads, bears striking witness to this phenomenon.

Given the present state of our knowledge, these noneconomic effects are not subject to quantitative analysis. This shortcoming unfortunately figures frequently in various types of decisions and the choice of investments.

CONCLUSIONS

The extraordinary growth in transportation is one of the dominant aspects of our time. It has far-reaching implications for our activities and behavior. The movement of goods to processing and consumption centers is assuming increasing importance and is being joined by the transportation of passengers.

The developing countries have not been untouched by this phenomenon of the modern world. Although somewhat delayed, their economic and human growth will slowly but surely be influenced by the orientation chosen for their transportation systems, in particular their highway systems.

Roads and highway transportation are essential to the growth of developing countries. This is because the absence and inadequacy of trade of all kinds prevents or limits the creation of a modern economic system making the best possible use of all available resources. It must be remembered that development is not only economic but also social and political in nature.

From this finding stems, the entire significance to be given to the integration of a transportation development plan into an economic and social development plan, with the latter setting out clearly distinct but coordinated objectives for these two areas (economic and social). The role of the transport planner is then to define the optimum transport system likely to achieve these objectives, although proceeding with the iterations necessary for taking into account the development effects contributed by transportation in itself.

In actual fact, in the absence of development objectives, the officials responsible for the transportation sector are frequently called upon to solve another problem, i.e., the allocation of limited funds (for road construction and maintenance, for example) between different regions and different road categories (primary, secondary and feeder roads - rural and urban roads). The current state of our knowledge concerning the development impact of transportation does not allow proceeding with such allocations in a satisfactory fashion. Nevertheless, the fact remains that a close relationship between master plans and development schemes should be kept in mind at all times by highway authorities in light of the numerous effects of highway construction and the fact that small changes in road design can contribute to economic developments other than those related to transportation. One such example is particularly striking in Sahelian countries. Road construction requires the creation of water resources, either by drilling into deeplying water tables or using small dams to store surface water. It costs little to make provisions for the wells drilled for road construction to be used subsequently for agricultural purposes, either directly or as participation in a prospecting campaign. It equally costs very little to treat road embankments near thalweg crossings as dams, thus permitting the storage of water upstream.

Developing nations need more than just master plans ; they must also draft highway policies with provision for attaining long-term goals. A sketch of the road system 15 or 20 years hence is very important, since it can help integrate present-day projects into the broader scope of the long-range plan. At the same time, however, stands must be taken on such varied issues as transportation regulations, in particular truck loads, highway taxation, the organization of construction and transportation companies, the organization of the many aspects of system management - of which highway maintenance is primordial - and, lastly, the training of the men needed to work on the roads and in the highway industry.

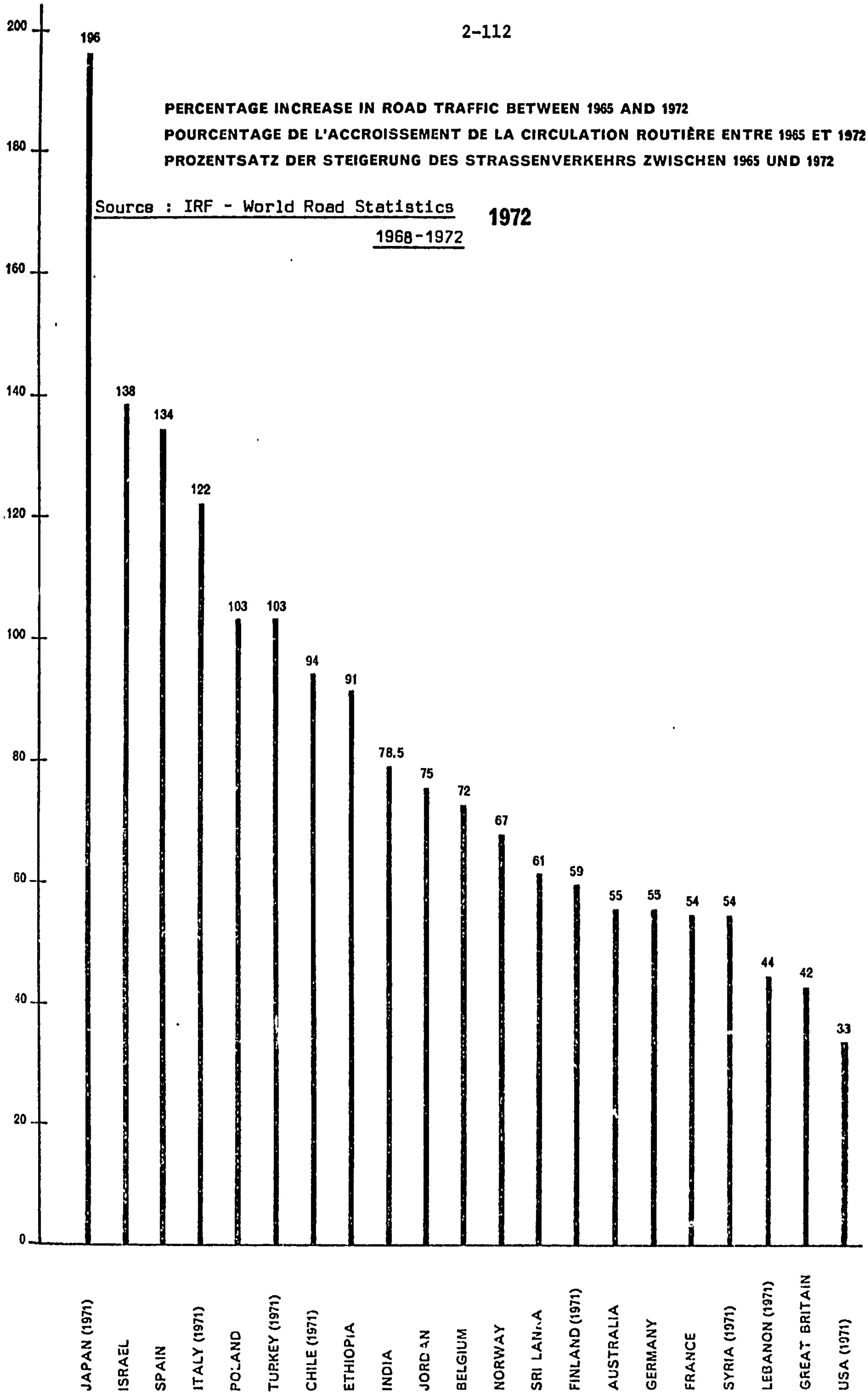
This may sound like an ambitious undertaking, but it is essential to prevent the waste of energy and ensure that highway transportation makes its best possible contribution to development.

L. Odier

March, 1974

PERCENTAGE INCREASE IN ROAD TRAFFIC BETWEEN 1965 AND 1972
POURCENTAGE DE L'ACCROISSEMENT DE LA CIRCULATION ROUTIÈRE ENTRE 1965 ET 1972
PROZENTSATZ DER STEIGERUNG DES STRASSENVERKEHRS ZWISCHEN 1965 UND 1972

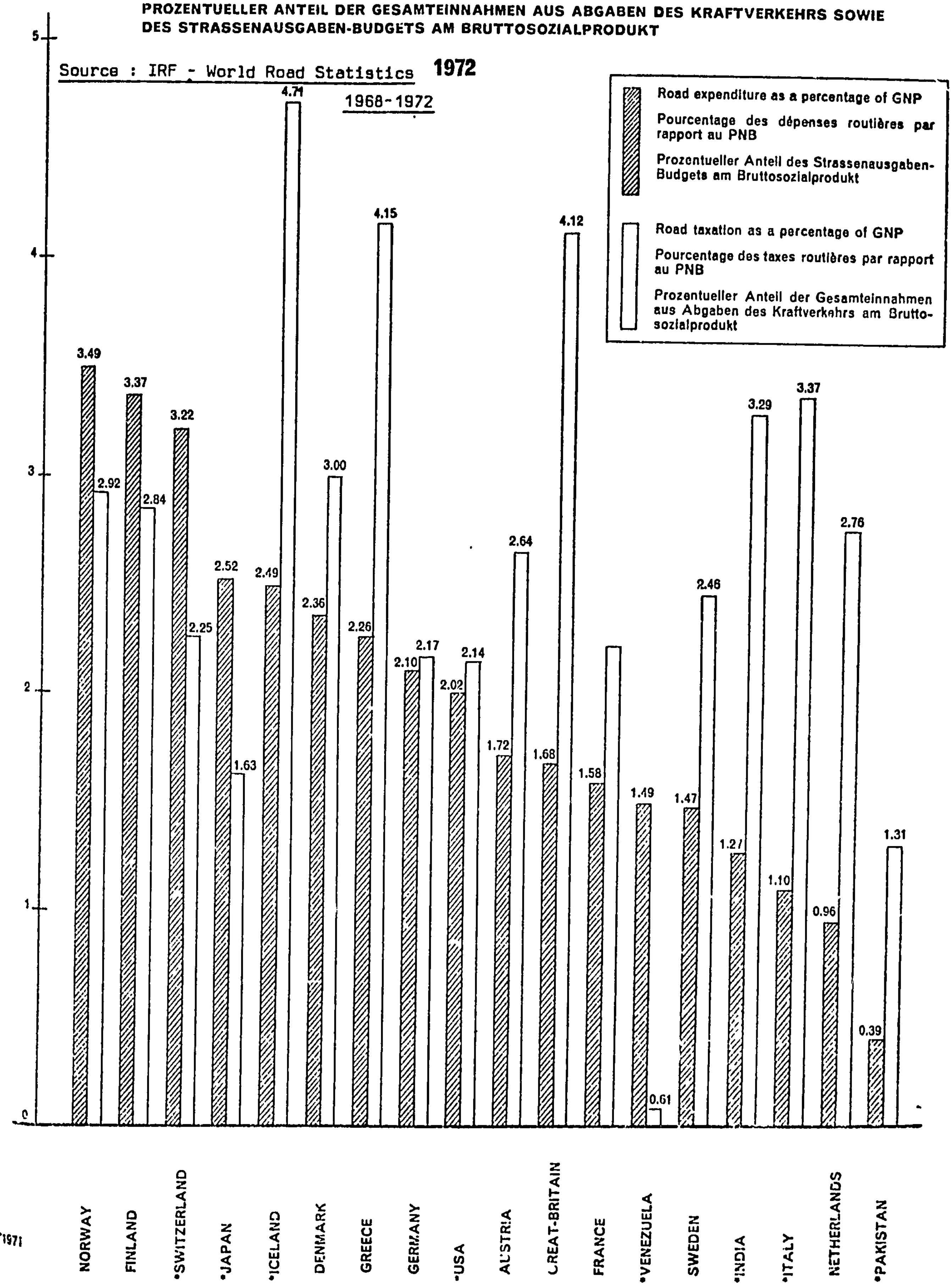
Source : IRF - World Road Statistics 1968-1972 **1972**



ROAD TAXATION AND ROAD EXPENDITURE AS A PERCENTAGE OF GROSS NATIONAL PRODUCT

POURCENTAGE PAR RAPPORT AU PRODUIT NATIONAL BRUT DU TOTAL DES TAXES ROUTIÈRES ET DES DÉPENSES ROUTIÈRES

PROZENTUELLER ANTEIL DER GESAMTEINNAHMEN AUS ABGABEN DES KRAFTVERKEHRS SOWIE DES STRASSENAUSGABEN-BUDGETS AM BRUTTOSOZIALPRODUKT



URBAN TRANSPORTATION PROBLEMS IN DEVELOPING COUNTRIES: THE ROLE OF TECHNOLOGY

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The role of technology in general and transport technology in particular in resolving the urban transport problem in developing countries cannot be either substantial or critical. Indeed, one could make the case that transport technology, as developed in North America and Western Europe, has in fact had a pernicious influence on urban life in the poor countries. Future transport technologies, again oriented primarily to urban problems in the industrialized countries, are unlikely to provide any important relaxation of the virtually insuperable problems facing the urban areas of the less developed world. They may in fact make things worse.

The purpose of this paper is to assess the nature and causes of the urban transport dilemma in poor countries to indicate how this differs from developed countries, and to examine the role that technology might, though probably will not because the problems are not technological, play in its resolution or alleviation.

There is little new that anyone can add to the burgeoning literature on urban problems. In addition, for a predominantly U.S. A.I.D. audience it takes an act of courage for a speaker to discuss urban problems of developing countries since most of you not only know what these problems are but have experienced them firsthand. Indeed, many of you have actively worked toward their resolution. Thus, much or all of what I have to say will be rather old hat to most of you. In the interest of brevity and to avoid belaboring the obvious, I will therefore outline a kind of composite urban scenario for developing countries in a series of statements, or propositions, which seem to be generally valid and widely accepted. While not all of them will apply to every major urban area of the underdeveloped world (after all, there are probably as many differences among Kuala Lumpur, Abidjan, and Calcutta as there are among the U.S., U.S.S.R., and Sweden) most of them appear to be relevant and of widespread if not universal application. I hope that putting together common knowledge in this form will lead to better understanding or additional insights.

One. The rate of growth of the nation states within which the urban area (or areas) are located will continue at the historically unparalleled levels prevailing since the end of World War II, namely, in the range of 2.5-3.0% per annum, and certainly at levels far exceeding those of the nations in the so-called developed or industrialized world. The reasons for this are well-known. They involve continued high birth and death rates.[1] The former are related to the large proportion of women in the child-bearing age bracket, the difficultires of mounting an effective birth control program in poor countries with low levels of literacy, scarce resources, inadequate communications and where religious or social attitudes and institutions (such as the extended family) impede conscious attempts to lower the birth rate. The high death rates presently encountered will continue to drop sharply in the face of rather simple applications of well understood and improved hygenic practices and disease eradication, even when nutritional standards do not improve materially.

Two. Urban growth will continue at a rate approximately double that of the national average because of (a) the "pull" of the city in terms of its real or imagined superior economic opportunities and amenities[2] and (b) the absolute or relative deterioration of rural life as agricultural efficiency declines or fails to improve (as in the Indian subcontinent and sub-Saharan Africa) and as, in many cases, rural insecurity persists or mounts (as in Indochina and Central Luzon) due to civil war, minority uprisings or banditry uncontrollable from the central regime. Even where agricultural efficiency improves, this will adversely affect employment opportunities and thus continue the rural to urban migrations. The "push" of rural aggravation (what Karl Marx referred to as "the idiocy of rural life") and the "pull" of urban life, however misguided, will continue to attract or coerce people to urban areas at a pace well in excess of the growth of national populations.

Three. Present levels of urbanization in the underdeveloped world are well below those in the developed economies. Most poor countries are between 20-40% urbanized (i.e., 20-40% of the national population living in towns or cities or over 20,000) compared with 60-80% for developed nations, thus providing an enormously greater potential for further urbanization than in the latter nations.

Four. Urbanization in the poor countries is now centered in one (or a few) giant metropoli or so-called "primate" cities. For example, 80% of Thailand's urban population is concentrated in the Bangkok-Thonburi metropolitan area and this area is over 30 times as large as the nation's second largest city, Chiang Mai. The ratio between the first and second cities in selected Southeast Asian countries is roughly as follows: The Phillippines, 12:1; Indonesia, 4:1; Republic of Vietnam, 6:1; and so on. This is substantially different from most industrialized countries (except some of the smaller ones like those in Scandinavia) where Zipf's law seems generally to hold.[3]

Not only does the primate city(or cities) predominate in size and influence over all other cities in the underdeveloped countries, in contrast with the developed nations, but its rate of growth is also generally faster than that of the second or third largest cities. This pattern may be expected to continue because the primate city will remain the focal point for additions to manufacturing capacity (because of scale economies and the availability of needed component inputs including parts, power and electricity), tourism and governmental functions, all of which are expected to grow more rapidly than the national economy as a whole, as indeed they have over the past two decades.

Programs for new towns, population and industrial dispersal will continue to be enormously expensive, administratively cumbersome and can be expected in general to fail, given the conditions in most poor countries. "How to keep them down in the Delta after they've seen Saigon," to paraphrase an old song, remains a worldwide phenomenon almost regardless of how intolerable the urban environment becomes.

Thus, a single primate city will continue to absorbe the bulk of urban growth. Such growth will not, in general, spread to medium or small towns in sufficient strength to take the pressures off the dominant densities, which are already high even by the standards of industrial countries.

Such metropoli also frequently contain the country's major seaport facility. Indeed, the entire surface transportation network of the country tends to radiate from the primate city which means that large traffic movements, both international and domestic, pass through often the most built-up downtown areas (e.g., Manila, Saigon, Bangkok.)

Five. A common feature of most primate cities in poor countries is the relatively small proportion of land devoted to transportation right-of-way. Typical figures for Madras, Bombay, Calcutta, Manila, Bangkok and Cairo indicate that between 5-10% of the city area is devoted to transportation right-of-way compared with the 25-30% figure believed necessary and in fact typical in the U.S. and, to a lesser extent, Western Europe. Narrow winding streets built in and for another era typify most primate cities in poor countries, although there are exceptions such as Taipei and the French-built cities with wide streets and boulevards as in Vientiane, Phnom-Penh and Saigon[4] (but not Cholon!).

The "capacity to congest" is therefore enormous and far greater than in urban areas of the developed economies.

Six. Present and future urban transport needs will continue to rely mainly upon motorized vehicles (private cars, taxis, buses, motorcycles, scooters, and three-wheeled vehicles.) This is largely because rail mass transit, subways, elevated railways and personal rapid transit are excessively capital intensive and costly (between $5-15 million or more per mile) and in terms of net benefits conferred scarcely justify the cost, especially in nations where the value of time is relatively low and hence the benefits of time-saving are negligible or nonexistent. Furthermore, in the generally sprawling megalopoli of the poor countries, such mass transit facilities cannot be made sufficiently ubiquitous, except at inordinate cost, to accommodate more than a small proportion of the journey-to-work or journey-to-market movements. Nor would their existence adequately cater to the needs of the desperately poor, who abound in cities such as Djakarta, Calcutta, Karachi, Manila, Limo, Mexico City, and Cairo, to name but a few.

In short, for the large amounts of desperately scarce capital and expertise, a reasonably ubiquitous, low-cost, well-managed rail mass transit system cannot be expected in t erms of the opportunity cost in most primate cities. Nor would it significantly relieve the actual and anticipated congestion in any event, as Owen documents in the cases of Caracas, Hong Kong, and Bombay.[5]

But perhaps a more fundamental reason to expect continuing reliance upon individual motorized vehicles (of an incredible variety) is their enormously high prestige value. Ownership of an asset, even as humble as a Honda, is a matter of substantial individual and even social importance, especially to a generation whose parents largely did without. Nor is there any gainsaying the sense of freedom and mobility derived from privately owned vehicles for reasons that have become commonplace. Thus, the private utility and prestige value of vehicle ownership remains high. Given the present extremely low levels of vehicle ownership, this will virtually ensure that the rate of growth of the motorized vehicle fleet, both public and private, will be at rates in excess of the anticipated growth of urban population.[6] Furthermore, vehicle ownership for the nation as a whole will continue to be heavily concentrated in the primate city.[7] One may therefore expect that the number of vehicles in use within the metropolitan areas will grow at rates approaching 10% or more. Some cities are already experiencing vehicle growth rates in the 15-20 percent range.[8] The number of people per vehicle (cars, trucks and buses) for a few selected Southeast Asian countries changed between 1960 and 1970, as shown in the following table:

TABLE 1

POPULATION PER VEHICLE

	1960	1970
Indonesia	577	371
Khmer	267	175
Laos	246	213
Malaysia	57	41
Philippines	151	80
Singapore	19	11
Thailand	269	111
Republic of Vietnam	251	145
U.S.A.	2.4	1.9

Similar evidence of trends in vehicle growth exists all over the developing world. When motorcycles are included, the growth is over triple the growth of cars, trucks and buses alone with consequences for urban traffic movement believable only to those who have lived with it on a regular basis.

If it were only a question of delay, congestion and pollution, this situation would be unpleasant enough. But the opportunity cost of the private car is potentially very serious indeed. For seven countries in Southeast Asia,[9] it is estimated that unless entry into the automotive age were restricted, the countries will spend a total uf $U.S. 91 biliion (in 1970 prices) for the purchase of land motor vehicles[10] over the next 20 years. Since much of this represents "consumption" in the national accounts (even though almost half consists of taxes and duties), the magnitude is very large when compared with developmental needs and investible resources likely to be available. Yet few countries have been prepared to slow down the growth of the private automobile for reasons varying from the fact that it is a difficult and unpopular thing to do, that it would cause unemployment in au.o related enterprises, to a failure to recognize the direct and indirect costs involved.[11]

Unless strong measures are taken, the probability is high that the number of vehicles per capita and per hectare attempting to navigate within the primate cities will grow at rates three to four times the growth of the national population. The rate of growth will be even higher in countries were income per head is growing rapidly, such as Thailand.[12]

<u>Seven</u>. Most large metropoli in the developing countries already suffer from pollution and congestion, often on a scale approaching that of Tokyo. Given the probably future trends, these can be expected to increase at an exponential rate. The congestion and pollution have, of course, emerged long before the motor vehicle or bus have reached anywhere near the present proportions in the U.S. or Western Europe for two main reasons. First, and most important, is the bewildering traffic mix in the right-of-way. The use of sidewalks for parking motorcycles and cars, for petty hawking, trading, small shops, and other highly individualized commercial dealings and, in <u>very</u> poor countries, for "family" living and begging, forces pedestrians into the right-of-way where they mingle with animal and human propelled carts[13], batjeks or trishaws, in addition to trucks, buses, cars, jitneys, and taxis of every kind and in every conceivable state of disrepair. The traffic mix is thus unlike anything that has occurred in the developed countries where animal powered vehicles did not long co-exist with the internal combustion engine and the variety of conveyance was much more homogeneous. But perhaps worse than the mix, or partly because of it, is the complete lack of discipline. The disorganization of the traffic flow combined with the heterogeneous mix produces congestion and pollution of a type seldom if ever encountered in the industrialized nations.[14]

Second, the pollution levels already achieved often rival those of Tokyo and New York, not so much because the automobile traffic is equally heavy but because the enormous increase in diesel-fueled motorcycles and trucks more than compensates for the relative dearth of cars. Cities such as Saigon and Taipei are thus polluted long before the automobile has appeared in large numbers.[15]

The foregoing statements or propositions relating to past and future trends protray a dismal future for some of the world's great or at least most interesting urban areas unless some rather drastic measures are taken to prevent worsening of the present situation. Obviously, if the situation becomes sufficiently intolerable, as it does from time to time, and thus induces, for example, the citizens of Bombay in their frustration to set fire to the commuter trains, the net attractiveness of the city vis-a-vis the rural areas may shift. But the willingness of urbanites to suffer, especially in poor countries, and the misery in much of the countryside, makes this a largely theoretical proposition and one totally inadequate for the policy maker to accept.[16] The necessity to "do something" is everywhere apparent in the primate cities of the developing world.

At this point we come face to face with one of the fundamental problems of underdevelopment—namely, the capacity to respond effectively to mounting problems even assuming the urban planners know exactly what should be done—a large assumption indeed! Without pretending that the industrialized economies have done much better in their responses to urban problems, transport and otherwise, let me at this point spell out a likely scenario of the response to growing urban crises in a typical underdeveloped country faced with the past trends and present realization noted above.

The responses of local and/or national governments to the growing chaos are likely to be as follows:

(a) Request support for a large scale ($1 million to $3 million), time-consuming (2-3 years) study by a foreign engineering consulting firm. The request for funding will initially be to an international lending agency but when turned down (as is probable), the country will turn to U.S., Japanese or German private consulting firms who will accept on the likely basis that they will participate in whatever construction is to be done.

(b) Prior to or during the course of the study, the government (or appropriate authority) will fix the fares for a privately or publicly owned bus, jitney or taxi service (in response to complaints about rising living costs) at levels that will guarantee that supply will regularly lag behind demand, thereby leading to deteriorating service, undermaintained and unsafe vehicles and overly tired drivers who not only must haggle over every fare, despite "fixed" rates, but must also operate 10-15 hours per day in heavy traffic to make ends meet.[17]

(c) Scarce capital will be used to initiate or complete one or two token urban expressways, which will not relieve congestion, and at the same time—because of budgetary limitations—maintenance of other urban arterials will be neglected. This will have the twin objectives of removing the poor from along the construction right-of-way and, as a showcase investment, has implications of progress and modernity.

(d) The composition of traffic will continue to be ignored pending completion of the urban study and the traffic laws will remain unenforced mainly because the police force is underpaid and hence not concerned with carrying out unpleasant duties that do not have incremental payoffs.[18]

(e) When the urban transportation study is completed, its recommendations--even when they make sense (not all recommendations are sensible as Malaysian officials discovered following a study of Kuala Lumpur some years back)--will generally be ignored for two main reasons. First, it is likely that the political, economic and even the traffic situation will have changed in the interval and the recommendations do not conform to some preconceived notions of the new regime or the altered circumstances. But second, and most important, the human and capital resources required to implement the recommendations effectively are simply not available. In particular, the administrative willingness and/or ability to innovate probably does not exist. This is a delicate subject not often discussed, especially by the consulting firm or foreign planner within a particular country. Even reasonbly obvious remediable measures may run afoul of administrative timidity, ineptitude and inertia. As Mowll puts it, even where a "planner's recommendation . . . seems reasonably clear . . . the real question is, how can the public and private decision-makers be made to follow the planner's lead? Can entrenched interests, both in the government and out, be persuaded to change their policies for reasons of community growth and welfare in a land in which tradition tends to oppose change."[19]

The situation is even more prone to inertia and inaction when the needed measures are <u>not</u> so obvious. As the Calcutta Basic Development Plan noted: "Over the past two hundred years many boards and committees and commissions have met and deliberated on the problems of the city and issued reports calling for remedial action. The improvements that were subsequently made, if indeed any action was taken, were invariably piecemeal, sporadic, and inadequate to meet the needs of the rapidly increasing population of Calcutta. This has continued to be the case."[20]

The situation, therefore, in the primate cities will likely continue to deteriorate: random, ad hoc palliatives, such as construction of an occasional overpass, elimination of a dangerous roundabout, conversion of some arteries to one-way systems, will be attempted and will provide evidence that the government is "doing something." External events, such as the sudden rise in fuel prices, may help to decongest as recently has happened in Saigon, Manila,[21] and elsewhere. Long range policies of population dispersal will be announed (Republic of Vietnam, Taiwan, and others)whose goals will be to funnel population growth away from the primate city but the details of how such policies are to be implemented will be lacking, and, in any event, the target date will be close to the end of the century.[22]

<u>Consequences</u>

The consequences of an inability and/or unwillingness to act will obviously be adverse though not catastrophic. While pollution and congestion will rise, this will be gradual and people will learn to accommodate and accept this. In any case, the capacity for suffering in poor countries is large and other causes of misery among the urban poor are far more critical. There will thus be no great outcry and some, with only a hint of cynicism, may view the traffic chaos as "modern" in the sense that the city has "progressed" to the point where the traffic situation is as bad as Rome or New York.

But there are consequences of a more fundamental sort. The opportunity to benefit from the mistakes of the West will be lost. Vast expenditures on privately owned vehicles will be made at enormous opportunity cost. Balance of payments deficits will rise because vehicles, parts and fuel[23] will be imported in increasing amounts. This will provide incentives to establish inefficient domestic or regional automobile production or assembly facilities which will be sustained at high cost levels by direct subsidy and/or high tariffs. Scarce resources will be diverted from other, more pressing needs, as the economy tried to respond to the insistent demands of the automotive age. Resource allocation will be further distorted as increasing urban overcrowding diverts attention away from the critical agricultural sector. This will be even more pronounced if urban areas become the seat of growing political discontent, which is especially likely, since they contain the bulk of the educated unemployed.[24] However, improvement of urban areas at the expense of the countryside is likely to encourage rural to urban population movements even beyond present rates as the gap between rural or urban living conditions widens. The problem then becomes cumulative and urban improvement, through such resource reallocations, becomes self-defeating.[25]

As a result of overcrowding, land values will rise[26] as will the cost-of-living and the incidence of the latter will weigh most heavily upon the urban poor. Thus, urban income inequality may be expected to rise, expecially since the urban well-to-do are in a better position to reap the benefits of rising land values and respond to other economic opportunities that accompany the growing population.

The Role of Technology

With very few exceptions, approaches to modifying the above scenario do not involve technology. The technology of the automobile and right-of-way construction did not cause the problem. Most cities were congested prior to the car.[27] But automotive and transit technology at least permitted the urban areas to grow to the present extent. Improvements in emission controls will help the pollution problem and if they make the cost of the automobile much higher could slow down the growth of vehicle ownership, especially if fuel prices stay high as they are likely to do. Enforcing emission standards will be extremely difficult, however, and there will be considerable scope and incentive for evasion.

Transit technology will not do the job for reasons already noted unless rather firm restrictions are placed on the use of private automobiles.

If the latter occurs (less likely as a result of administrative actions and more likely because of higher prices for fuel and vehicles), a more sensible and less costly approach than rail mass transit would be to utilize existing streets and develop a more ubiquitous public bus system. There are encouraging signs of this beginning to happen. If technology could develop a low-cost, non-polluting bus, with low operating cost characteristics, this might prove to be a significant attack on urban problems. The incentive will still be high, however, for grandiose and expensive schemes involving subways and other exotic modern techniques.

While technology can help in various marginal ways, the most reasonable approaches are essentially non-technical. They have often been noted and I will merely list the most obvious ones here.

(a) Institute a system of full user charges, including peak/off-peak pricing for users of urban rights-of-way. The automobile has been heavily subsidized in the past in all cities which, when added to its convenience, encourages its use when the appropriate policy is one of discouragement.

(b) Enforce traffic laws and discipline

(c) Spread peak-hour traffic over longer time intervals by staggering beginning and closing hours of work

(d) Relocate industry and housing so that long-crosstown journeys to work will be reduced

(e) Experiment with low-cost or even free public bus transit

(f) Separate the various types of traffic by special lanes for motorcycles and animal and human propelled vehicles and have a reserve bus lane at peak hours

(g) Use traffic signals geared to reflect traffic demands

(h) Prohibit parking on major thoroughfares

(i) Remove rail and truck terminals from congested areas

(j) Require heavy trucks to make deliveries at night or before 6:00 a.m.

These and many other recommendations have often been made. Essentially, they boil down to a better use of existing facilities. But in the final analysis, they are unlikely to be done partly because they do not excite the imagination to the same extent as massive new and highly visible investments and partly because there are genuine difficulties with them. Given the generally greater dearth of effective and innovative administration talent in developing countries, the prospects of vigorous actions being taken along any of these lines are slim. What official wants to be responsible for taxing or restricting the automobile and Honda to such an extent that their use will sharply diminish? Who will take responsibility for reducing output and especially employment in those industries related to the automobile? Who will attempt the hard task of removing basiness and/or housing from present locations?

More fundamentally, so long as people keep moving from the rural areas to the primate city at past rates, there can be no important and permanent improvements in urban life, including urban mobility. The need is clearly to channel population growth elsewhere which implies an effective population and migration strategy. The problems of controlling population size in poor countries are well known. Similar problems beset migratory policies that seek to reverse natural movements. In short, these are areas where public policy is and has been singularly ineffective.

We have been advised at this conference that U.S. A.I.D. is shifting its emphasis away from urban toward rural areas. If what I have argued is true, this is not surprising. Indeed, such a shift may benefit the city more profoundly than attempts to tackle urban problems directly.[28] If A.I.D. can assist in so improving rural life that the net attractiveness of the city is sharply diminished, this will be a major accomplishment and will directly benefit both urban and rural areas. Rather than lament this shift, as some have done, it should be encouraged.

FOOTNOTES

1. Crude birth and death rates for the less developed countries are about double those of the developed countries. Birth rates for the former are around 38-39 per thousand, while death rates are around 16-17 per thousand. There are many references. For a general discussion of the long-range population outlook see Farmer, Long and Stolnitz (eds.) World Population--The View Ahead, Bureau of Business Research, Indiana University, 1968, and especially the paper by Miłos Macura, "The Long-Range Outlook--Summary of Current Estimates," in ibid., pp. 15-42.

2. It is generally true that incomes per head in urban areas are above the national average and well above incomes in rural areas. Industrial wage rates and consumption per head are often several times higher in urban areas than rural areas. However, the degree of income inequality within the primate city is greater than that for the nation as a whole. The cities contain some of the poorest living conditions and lowest paid workers in the entire country along with the highest paid professionals, businessmen and absentee landowners. Furthermore, unemployment and underemployment rates are higher in urban areas than elsewhere, although the definition of rural unemployment and underemployment raises serious measurement problems. (A discussion of why this still induces rural to urban migration is contained in M. P. Todaro, "A Model of Labor Migration and Urban Unemployment in Less Developed Countries," American Economic Review, March 1969, pp. 138-147.) Whether urban economic advantages are real or imagined depends in part upon whether one examines average incomes per head or the distribution of income. (For details and discussion see Gunnar Myrdal and others, Asian Drama, Vol. I, Twentieth Century Fund, New York, 1968, pp. 467-471 and pp. 575-577.) In any event, the range of opportunities is certainly greater in urban areas and the glamor of "city lights" is high even in Calcutta.

3. This "law" asserts that if the cities of any country are ranked in descending order of population, the size of each city will generally be inversely proportional to its rank order. Thus, $P_n = \frac{Z}{n}$, where P_n is the population of the city whose rank order is n and Z is a constant differing among countries. If the law held completely, Z would be the population of the primate city. Application of this so-called "law" to most poor countries reveals wide discrepancies, as would be expected from the foregoing comments.

   For an application to selected Southeast Asian nations see Arthur D. Little, Southeast Asian Regional Transport Survey, Book Two, Part One, Asian Development Bank, 1972, pp. 326 ff. The basic source is G. K. Zipf, National Unity and Disunity, Bloomington, Indiana: Principia Press, 1941. For a discussion of this and other aspects of urban size distribution see B.J.L. Berry, "City Size Distribution Development," Economic Development and Cultural Change, Vol. 9, 1961.

4. It is worth noting, however, that the French planned Saigon for a size of 300,000. It is now about three million and thus has its share of narrow streets "grafted on" as it were.

5. Wilfred Owen, <u>The Accessible City</u>, The Brookings Institution, Washington, D.C., 1970, pp. 40-43.

6. Such growth rates will also exceed those of the developed economies. As Lionel Odier notes (see his paper in this volume), "Whereas in the U.S.A. the number of motor vehicles increased by a factor of 2.5 between 1949 and 1972, the comparable figure was 4.8 for Australia, 6.5 for Nigeria and even 10 for Uganda."

7. For example, while Bangkok contains only about 8%of the Thai population, almost three quarters of the automobiles are concentrated there. Other cities show similar disproportions as follows:

City	Percentage of Population	Percentage of Automobiles
Bogota	11.6	35.6
Bombay	1.1	14.5
Caracas	19.3	36.1
Djakarta	3.8	36.6
Mexico City	14.8	45 5
Nairobi	4.7	59.4
Panama City	30.0	66.1
Rio de Janeiro	4.7	11.4
Sao Paulo	6.1	25.8
Seoul	17.6	46.7

Source: R.S. Smith, "Financing Cities in LDC's," <u>Finance and Development</u>, March, 1974, p. 10. Data refer to the latter half of the 1960's.

8. Owen, <u>op. cit.</u>, pp. 19-20.

9. Laos, Republic of Viet Nam, Thailand, Malaysia, Indonesia, Singapore, and The Philippines.

10. <u>Southeast Asian Regional Transport Survey</u>, op. cit., Book One, pp. 142-143.

11. For a brief discussion see George W. Wilson, "Transportation Policies and Planning Goals for Taiwan," <u>Industry of Free China</u>, August 25, 1972.

12. It is therefore no accident that Bangkok has a traffic and congestion problem virtually unparalleled in any other major city, Only Rome or Tokyo come closer to complete paralysis.

13. The effects of low speed users are often serious. It has been estimated in Bengal that the effects of bullock carts sharing motorways are so "detrimental to capacity that 100 bullock carts per hour require about six times as much road space as the same number of cars." (Infrastructure Problems of the Cities of Developing Countries, An International Urbanization Survey Report to the Ford Foundation, July, 1971, p. 197). In addition, heavy carts and chronically overloaded vehicles of all kinds to severe damage to the street surface. Attempts to control overloading are regularly doomed to failure because of enforcement problems. Thus in the Republic of Vietnam, while maximum loads for trucks have been established at eight tons or lower under the Vehicle Load Control Program, actual loads frequently exceed 20 tons.

14. As my colleague Charles Stonier puts it, "Driver discipline may be poor because of laxity in law enforcement which results partly from corrupt practices, but more importantly from insufficient traffic police equipment, including communications. . . . Lack of vehicle inspection (in Djakarta, for example, gas stations provide few services and cars are not routinely checked for oil, water and tire pressures) increases the rate of breakdowns and disabled vehicles are frequently left in the way of the traffic flow. It is customary to leave vehicles in the way of traffic after collisions until policy reports are fully completed." (Private communication from the Southeast Asian Agency for Regional Transport and Communications, SEATAC, Kuala Lumpur, Malaysia, June 26, 1974.)

15. In some cases, for example Ankara, pollution levels are high not only because of automobiles and heavy industry but also due to location in a bowl-like enclosure and the prevalent use of particularly dirty fuels for heating and cooking. In Ankara's case, further growth along the lines indicated above can only make the already unhealthy situation worse. The Wall Street Journal reports that because of pollution, "the number of serious ailments in Ankara has risen sharply" and "the duty tour for American servicemen and diplomats has been reduced from four years to two years, and a 10% pay differential has been given them because of the health risk." (Wall Street Journal, Monday, June 10, 1971, p. 1.)

16. John P. Lewis' eloquent plea to the Indian Government to arrest the further growth on India's 12 largest cities seems, however, to have gone unheeded or, if tried, to have failed although the growth rate of Calcutta has declined. (Quiet Crisis in India, Chapter 7, The Brookings Institution, Washington, D.C. 1962)

17. In Cairo, for example, bus fares have been unchanged since 1953 and taxi fares since 1950 with present day consequences vividly described by John Waterbury in Cairo: Third World Metropolis, Part II, Transportation, AUFS, Northeast Africa Series, Vol. XVIII, No. 7, September, 1973.

18. Gunnar Myrdal reports that he once asked the chief police officer in a district of New Delhi why he did not order his policemen to enforce the rules, especially against the taxi drivers' habits of ignoring them completely. The officer replied: "How could I? If one of them went up to a taxi driver, the driver might say: 'Get away, or I will tell people that you have asked me for ten rupees.' If the policeman then pointed out that he had not done it, the rejoinder of the taxi driver could be: 'Who would believe you?'" (Myrdal and others, op. cit., p. 955, f.n. 1)

19. J. U. Mowll, Examples of Taiwan's Transport Problems, Background Paper for U.S.-R.O.C. Seminar, Berkeley, California, July 29-30, 1974, mimeo., p. 5.

A classic illustration of inaction is provided by Bangkok which for over three years has been receiving West German aid to study and make recommendations to alleviate the excruciating traffic congestion which is probably worse than that of Rome. A whole series of substantive recommendations by the German team, some of them relatively costless, have regularly been made. Almost none have been implemented. As reported in the Bangkok Post a German Embassy source noted: "A total of 4 million DM has been spent on traffic studies yet nothing useful has been achieved." Further funding was threatened with cessation because "The German Government considers it useless to invest in any field that bears no fruit for either party". Bangkok Post, Vol.XXVIII, No. 195, Tuesday, July 16, 1974, pp. 1 & 3.

20. Basic Development Plan for the Calcutta Metropolitan District, 1966-1968, Calcutta Metropolitan Planning Organization, Government of West Bengal, 1966, p. 3.

21. Manila has been "helped along," as it were, by martial law.

22. The difficulties besetting various schemes of transmigration have been examined in Gunnar Myrdal and others, op. cit., pp. 1266-72 and 2139-2147. The general conclusions are that past migration policies seeking to decongest certain areas (e.g., Java) and/or open up sparsely settled lands where agricultural potential, even including plantations, is substantial have been extremely costly, have not offset the population densities of the crowded regions to any important degree and too often have served as an excuse to avoid programs of birth control (on the latter point see ibid., pp. 2147-2149.) While these schemes are not directly related to a program of de-urbanization, the problems encourtered are similar. One cannot be sanguine that the substitution of "new towns" of "centering" for settlement of empty economic spaces, will meet with any greater success than previous migratory programs.

23. Except in those countries having oil reserves.

24. As has been noted, "urban populations have more access to, and influence on, political processes. As (urban) conditions worsen, towns

are likely to demand and get progressively larger proportions of the national pie at the cost of the countryside." (Shanti Tangri, "Urbanization, Political Stability, and Economic Growth," in Roy Turner (ed.), India's Urban Future, University of California Press, 1962, p. 209). Stanislaw N. Welliscz notes that "the policies pursued by the developing countries of Asia favor urban areas to the detriment of rural ones, causing an uneconomically fast rate of urbanization," ("Economic Development and Urbanization," in Jakobson and Prakash, Urbanization and National Development, Sage Publications, Beverly Hills, California, 1971, p. 45. See also M. Lipton, "Strategy for Agriculture: Urban Bias and Rural Planning," in Streeten and Lipton, The Crisis of Indian Planning, Oxford University Press, 1968).

25. See, for example, Wellisiz, op. cit., pp. 52-53.

26. As Prakash points out: "In most of the Asian cities . . . increase(s) in land values . . . have been phenomenal. A recent study of several selected Indian cities revealed that land values during the 15-year period 1950-65 increased in some cases by 18, 43, or 68 times. . . ." (Ved Prakash in Jakobson and Prakash, op. cit., p. 206). Sah notes that "in Singapore, the price of residential land within a five-mile radius of the city centre was M$1.5 per sq. ft. in 1962 and M$3.0 per sq. ft. in 1964. . . . In the new township of Petaling Jaya near Kuala Lumpur, land prices increased of 375 percent in four years. In Karachi, the cost of land in the Pakistan Employees Housing Society area increased from Rs. 3 to Rs. 100 per square yard between 1951 and 1965 . . . Land prices in central Seoul and Taegu . . . have increased by 3,000 and 1,000 percent respectively within the last 10 years." (J.P. Sah, cited in ibid.)

27. For a description of pedestrian and vehicular traffic congestion as far back as ancient Rome see Jerome Carcopino, Daily Life in Ancient Rome, Yale University Press, 1940, pp. 46-51.

28. Todaro stresses the need to make rural life more attractive and suggests that "instead of allocating scarce capital funds to urban low cost housing projects which would effectively raise urban real incomes and might therefore lead to a worsening of the housing problem, governments in less developed countries might do better if they devoted these funds to the improvement of rural amenities." (Op. Cit., p. 147).

COMMENTS ON THE TRANSPORTATION PAPERS

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I concur with George Wilson that a solution to the Urban Mass Transit problem is as difficult to accomplish in the major cities of the developing world as in the developed world. By George's definition, our firm would qualify as one of those consultants brought in to propose a solution. Perhaps it would help clarify the problem if I present some of the reasons why I believe a transfer of our most advanced design technology in mass transportation might really not be in the best interests of the developing countries.

Most major cities in the developing countries are situated in hot, humid climates. Many of them are close to the sea or major rivers so that they also have a high groundwater table which inhibits underground construction. Presently most transport is by bus and most of these buses are in a very advanced stage of dilapidation. When they run, which is spasmodically, they belch noxious smoke and fumes. Virtually none are airconditioned. Their interiors are packed with humanity and, people frequently are hanging all over the exterior as well. The volume of occupancy per bus is high, but the passenger fares are extremely low...frequently only one or two cents per ride. For political reasons, it is impossible to increase the fare, and under the present fare structure, the operators cannot accumulate reserves for new buses and provide better service. In many cases, the fares do little more than cover wages and fuel costs. Because these buses are old and dilapidated, and break down frequently, there are many complaints of unreliable public transport. Therefore, the government officials pine for a modern mass transit system free of the heavy traffic congestion of the city streets and free of the noxious fumes and air pollution contributed by the internal combustion engines.

When the consultant first interviews the government officials as to their interests and desires, they universally suggest that a modern metro system at least as efficient as those in France, Moscow or Frankfurt is the only practical solution they can consider. They have no concept of the capital costs involved in building such a subway, which can run over 20 million dollars per mile. They have no realization that the carrying costs for the capital construction plus amortization of the subway cars plus operating costs for the facilities would make the out-of-pocket cost per ride more like 50 cents per trip rather than the two cents now charged per passenger.

In some of these congested cities people receive wages of only 50 cents to $1.00 a day, and ever the present subsidized bus fares are a burden on the lowest paid workers. However, the officials having read all of the scientific information on the new technology available in America for mass transit, speak repeatedly of their need for the most advanced linear induction propelled cars, air cushion vehicles, and even small personal rapid transit vehicles suspended on monorails. It is obvious that they are looking for the romantic technological solution rather than the pragmatic economic solution. So, in reality, they look for solutions that have glamour but no glimmer of a chance of being implemented. Unfortunately they think only in terms of building monuments as modern and beautiful as those proposed for the most technologically advanced countries of the West without really understanding the economic implications. Consequently if we are to help those developing countries by a transfer of our best technology, it must be a technology that measures not only the cost effectiveness of alternative solutions, but the economic capabilities of the developing countries to find the capital to fund these projects in competition with other high priority projects which are equally in need of capital. In other words why consider any subway where the fares to amortize are far beyond the economic capacity of the present users of the buses?

It seem cruel to say that these people must somehow learn that it is not what they want, but what is the optimal compromise they can afford that represents the adopted solution of their transport needs. Therefore, we could probably do more good in solving mass transit problems for most developing countries if we set up central maintenance shops, with the best diagnostic facilities, and rebuild equipment so that the thousands of dilapidated buses could be efficiently overhauled for greater reliability and reduced consumption of fuel and lubricants. Another major improvement for most of these cities would be a centrally-located bus terminal similar to those of the New York Port Authority. More efficient loading and dispatch of bus passengers would remove a major source of congestion in the inner cities. It is frightening to see prospective bus passengers rushing across the streets willy-nilly hoping to catch a bus back to the suburbs. Moreover, a capital investment in new buses--particularly diesel buses that are much more economical of fuel--would be particularly appropriate at this time when fuel costs have risen so high in the developing countries that increases in fare have become mandatory.

The thesis that George Wilson has presented--although in a light vein--is basically terribly serious. The transportation situation in many large cities of the developing world has really become desperate. Since I have worked in virtually every country he has discussed--Indonesia, Thailand, etc.--I can attest to the fact that the traffic situation in Thailand is even worse than in Tokyo, that means that it is about the worst in the entire world. It frequently takes two hours during rush hour to go two miles in Bangkok. You can walk faster than you can drive. You burn up large quantities of gasoline waiting in stalled traffic. The economic cost of wasted imported fuel is high but the pollution levels have risen to alarming levels in many developing cities to represent an even more serious future threat to these communities.

But if you consider the traffic and air pollution bad now, what will happen in the next twenty years? The statistics simply are staggering. For example, Greater São Paulo, Brazil, which has now approximately 10 million people, is projected to have 20 million people in the next twenty years. Just visualize a new city as big as New York and Tokyo combined. When you appreciate the magnitude of the traffic congestion and the urban problems they have now in São Paulo, can you visualize the magnitude of the problem they will have then? Brazil is building nearly 1 million cars a year in São Paulo and half of them are remaining there. Maybe our transport technology cannot find a solution for São Paulo. Maybe the big cities will stagnate and die. Even with mass transit we haven't found the technology to solve rush hour congestion in New York; so I am that optimistic that we can find a simple solution for the developing world.

Now, let me discuss the problems that Mr. Odier has presented on rural transportation in the developing countries. It has been my personal observation the people in the cities are far better off economically than rural people in developing countries. Most of the loans and contributions from the international lending agencies are for projects that create jobs and benefits making a better life for the people in the cities. Meanwhile the people in the rural areas get little benefits from these investments and keep getting poorer by comparison. This is obviously a matter of great concern to development planners and the thrust of McNamara's latest efforts at the World Bank is to concentrate on finding an answer to the question. "What can we do to help the poorest 40 percent of the people in the developing world?" Economists and engineers are presently testing every possible development model to find a methodology that would permit monies to be selectively pumped into the economic development in the poorer areas of the developing countries. For example, we recently completed a major development plan for Iran which focused on the question, "Can we control a differential rate of economic growth between poorer and richer provinces?" Until some rational basis for answering this question is reached, it will be impossible to maximize the development benefits of foreign investment. Much thought is now being given to methods measuring the benefits to the rural communities from improvements to feeder roads, improvements to farm technology, and water utilization. It is now in the area of feeder road construction that great technological transfers might ultimately be possible. Since the volumes of vehicular traffic in rural areas are extremely low, the level of investment for feeder roads can only be justified at a very low magnitude. For most rural areas, the cost of a road with crushed stone aggregate base course and with an asphaltic waring course is prohibitive. Some new technologic advances involving the production of a hydrophobic compound that could make the natural soils water-repellent and trafficable is urgently needed if we are to ever construct really low cost roads that could be utilized in all seasons.

Subsequent to World War II, the U.S. Military spent millions of dollars at MIT, Princeton, and other Universities to develop this concept. Some technically successful solutions were found but, at that time, they were not practicable because the chemicals were too expensive. Perhaps it would now be appropriate to review the solutions originally proposed to see whether the scientific contributions in polymer chemistry made during the last 15 to 20 years have produced new economies in manufacturing that would now make the use of these hydrophobic compounds economically feasible. This would revolutionize present design procedures which provide very little difference in cost between two-lane all weather roads built for 10 vehicles a day and for 1,000 vehicles. In fact construction costs for rural roads have escalated faster than the inflation rates during the past two years so that the magnitude of investment required to build low volume traffic roads is becoming staggering. On one specific project, recently placed under construction in Paraguay, a simple calculation of interest on the capital investment plus the annual maintenance costs gives a value so high you could probably build a landing strip, charter a freight plane and fly all the commodities generated by the existing communities along the road free of charge and still save money, based on the volumes of traffic presently generated. Obviously every developing country dreams of a future growth that will be generated by the new highways. They always say, "If we could only open up the vast areas of virgin country then many of our unemployed would settle along the road and this would be a tremendous stimulus to the economic rebirth of our economy." Many roads are now being constructed based on this particular philosophy. A good example would be the highways in the Amazon basin, the Transamazonas south and the Perimetral Road north of the river. Each of these is over 4,000 kilometers long. The total investment for each is probably in the range of $300-$500 million. Because of the staggering investment cost, every conceivable construction economy was made. The roadway is of earth—in some cases with a little laterite topping. The bridges are of wood. Since the road surface is not waterproofed, the maintenance costs each year will be extremely high. During heavy tropical rainstorms, the steep side slopes will badly erode, gullies will form, sections of road will be under water, and spongy areas will develop so the same section of road will be impassable during the rainy season--which in some areas lasts for several months of the year. In some sections of the Amazon traffic now is probably not more than 5 to 10 vehicles a day. Considering the capital investment and maintenance, the cost per ton mile of cargo hauled is astronomical. While the entire road is not now justifiable by any present economic efficiency techniques, in the larger context of over-all country development, it may turn out to be one of the most profitable long-term investments ever made in Brazil. Every prior development road in Brazil--for example, the Belém/Brazilia Highway--was similarly criticized as a frittering away of the national resources. But, in fact, over the past ten years, the traffic on the Belem/Brazilia built up from 5 vehicles a day to a couple of thousand vehicles a day and ultimately led to the economically-justifiable investment of constructing a year-round trafficable pavement surface.

In summation, the people in the developing world are looking to the developed countries like the United States for the transfer of a super-marvelous technology that will suddenly give them instantaneous solutions to their most pressing rural and urban transportation problems. They want to adopt only the most advanced technology so that everyone will know they are in the forefront of advanced worldwide technology. They ask for the autobahn even when they only have 20 vehicles a day and they ask for modern subway systems when their workers don't have the economic resources even to pay realistic bus fares. Even though we can give them access to the most modern design technology available, it may propose technical solutions not in their best interests--considering the competing demands and shortage of investment capital. It would appear therefore, that our greatest efforts should be directed toward the transfer to them of a technology that places great emphasis on economic efficiency (benefit/cost relationships) to insure that optimal solutions rather than optimal technology, is achieved.

TECHNOLOGY UTILIZATION IN WATER RESOURCE DEVELOPMENT AND MANAGEMENT

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The technology that has been created in the advanced industrial nations for use in the management and development of water resources has been spectacularly successful. The provision of safe water in abundant quantities and at a low cost to the consumer has virtually eliminated the epidemics of water-borne diseases that plagued the cities in the 19th century. The construction of dams, levees and other engineering protective works for the control of flood discharges has prevented billions of dollars worth of damage that would otherwise have occurred. The provision of supplemental water for agriculture and livestock by irrigation from reservoirs or deep tube wells and by cloud seeding has helped to expand production while giving farmers an increment of protection against drought.

The transfer of this technology to the developing world has not always brought about similar achievements. It has commonly fallen short of the high expectations of the developing countries, and the consequences of its introduction have sometimes bordered on the disastrous. Whatever one may feel about the degree of success or lack of it, that has been attained, and to whatever one may be inclined to attribute the cause, there is widespread agreement that in the water resources area we should be doing much better.

Recently published statistics from the World Health Organization and a survey that I have recently completed for OECD permit an assessment of the record in potable water supply.

POTABLE WATER SUPPLY

Attempts to assess the world-wide conditions of water supply are of relatively recent origin. It was only in 1959 that the Twelfth World Health Assembly launched a "spearhead" programme to promote the provision of safe water in adequate quantities to communities lacking it. At that time serious shortages were known to exist, and the important role of water supply in public health was widely accepted. The programme was launched in the absence of estimates of the magnitude of the global defiencies.

The first estimates were made for the year 1961[1] and a second set of estimates have been released for 1970[2]. The 1961 estimates were for 75 developing countries and the 1970 figures relate to 90 developing countries which together account for 44 per cent of the total world population. The major significant omission is China.

Some of the results of these two questionnaire surveys are compared in Figure 1 and are shown together with targets suggested by the World Health Organization for 1980 at the end of the United Nations Second Development Decade. For statistical purposes the population is divided into urban and rural categories according to whatever definition is used in each country.

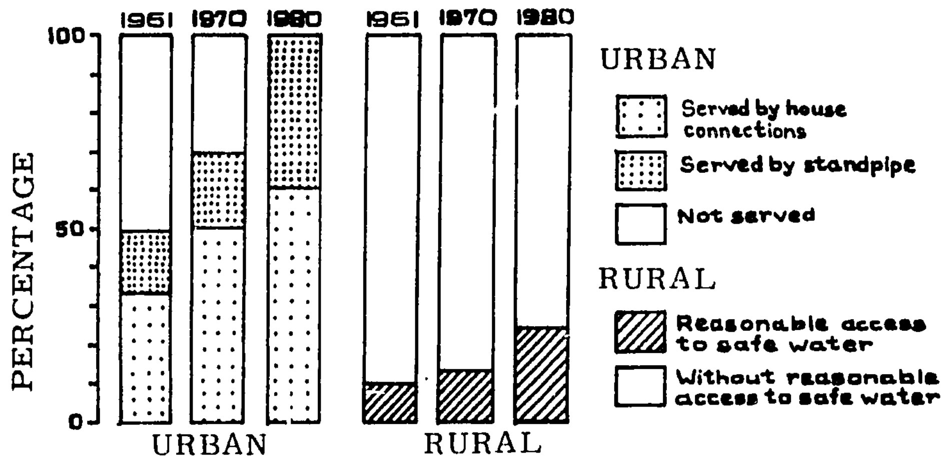

Figure 1 World Health Organization estimates of percentages of populations in developing countries provided with "safe and adequate" water for 1961 (75 countries), 1970 (90 countries) and targets for 1980 (90 countries).

Urban services are grouped according to whether the population 1) has a water connection within the house, 2) must carry water from a public standpipe or 3) neither. Rural dwellers are classified according to whether or not they have "reasonable access to safe water". Lack of detailed and precise information about rural water supplies makes the application of a very specific definition impossible. The guidance given for interpreting the phrase " reasonable access to safe water" is that reasonable access means "when a housewife does not have to spend a disproportionate part of the day in fetching the family's needs for water". Safe water "includes treated surface waters or untreated but uncontaminated water such as from boreholes, protected springs and sanitary wells. Others of doubtful quality will be classified as "unsafe".

The statistics are subject to several sources of error. They underestimate population served insofar as the reporting agency is uninformed as to local conditions or as to the activities of other government agencies. An agency may also consider a user lacks access to water because the agency did not provide the source. The reports overestimate the population served insofar as they assume that once a community system is installed by the builders it is used or operated by the consumers as intended. Many a traveller in a developing country has encountered an unused well or a distribution system where the treatment plant no longer functions. On balance, the statistics probably over-report the community services and under-report the achievements of individuals and informal local groups. For one country they may be far off, but the aggregate is probably moderately near the present situation.

On the basis of these data the World Health Organization concludes that for 90 countries about 70 per cent of the urban population and 12 per cent of the rural population, accounting for one-quarter of their total population are served by improved supplies (Figure 1). The 1970 situation marks a slight increase in proportion of rural population served between 1961 and 1970, after allowing for growth of 32 per cent in total population, and a more marked improvement in urban areas.

Change was far more rapid in Latin America than in Africa and Asia. For the total of 26 Latin American nations the proportion of urban users served from house connections and public standpipies increased from 60 per cent to 78 per cent, while the proportion of rural people with improved supplies mounted from 7 per cent to 24 per cent.[4]

These data do not permit a more detailed classification by settlement types. It is clear, however, that most of the unserved urban population are in the unorganized "temporary" settlements of the urban peripheries. As Figure 1 makes clear the major outstanding population in need of improved supplies is in the rural areas. It appears that only 12 per cent of the rural population is "adequately served". The distribution of this population among dispersed and concentrated settlements or in small towns of up to about 5,000 people is not known.

Considering what is possible within the Second United Nations Development Decade 1970-80 the World Health Organization has set a target of attempting to double the <u>percentage</u> of those receiving adequate supplies in rural areas. Many would say that the prospects of reaching such a figure are not high. By World Health Organization estimates it will require the design, financing, construction, placing in operation and maintaining of new rural water systems to supply an additional 20 million people <u>each year</u>. By the end of the decade it is hoped that 200 million additional people will have been served at a cost of $2,000 million for construction alone, at an average cost of $14 per capita. Average annual construction costs 1970-80 would be $280 million. This compares with the 1970 level of expenditure for construction estimated at $138 million, to supply 10.6 million people. In other words the 1970 <u>rate</u> needs to be more than doubled if the target is to be achieved.

Despite the ambitiousness of the target and assuming that it can be reached, it is expected that the number of those <u>not</u> served adequately will actually <u>increase</u> from 1,026 million to 1,081 million, (Table 1). The increase is not large in relative terms and given the margin of error that must be allowed in these data they may well imply no significant change. What this means is that in spite of great efforts the problems remaining at the end of the decade will be about the same as it was at the beginning. In at least one respect the problem will be worse. It is a common practice to bring improvements to those communities that are most accessible and most easily served. Hence the unserved population in 1980 is likely to be less easy to reach, and the average cost of supply is likely to be greater.

Table No. 1

Programme for Rural Water Supply in 90 Developing Countriess 1970 - 1980
(Population in Millions)

Type of Supply	1970		1980		Increase 1970-80	
	No.	Per cent	No.	Per cent	No.	Per cent
Access to safe water	140	12	357	25	217	155
Without access to safe supply	1026	88	1081	75	55	5
Total population	1166	100	1438	100	272	23

OBSTACLES TO IMPROVEMENT

Why is it that in so many low income countries the concern of the people to improve the basic amenities of water supply has been insufficient to force governments to provide minimal improvements for all? A common assumption is that it is a question of wealth. Only when per capita income rises to some threshold level will it be possible to meet the basic human right to clean water. This explanation is not well supported by the facts. Some countries with substantial gross national product per capita still fall far short of the goal, and others with lower income do substantially better. A review of the literature and a canvass of informed opinion permits a summary to be made of the most frequently cited obstacles. This accords very closely with a similar list obtained by the World Health Organization from its 1970 questionnaire.[3] Taken together these two sets of information suggest the following list of reasons for failure to make more rapid progress:

1) insufficient national or internal funds, a lack of national priority,

2) lack of trained personnel or manpower,

3) weaknesses in the organization and administration of national programmes, inappropriate administrative structures or the lack of national programmes,

4) insufficient external funds,

5) difficulties of operation and maintenance, shortages of supplies, equipment, spare parts and insufficient local production,

6) inadequate or outmoded legal framework.

All of these reasons can be substantiated with some evidence and shown to be at least partly true for some countries. Certainly efforts to remedy these deficiencies have been and are being made. I am sceptical that such efforts by themselves will be well rewarded however because the list of obstacles neglects two aspects of water supply that give quite a different perspective. First, a high degree of confidence is implicitly expressed in the expert's view of what is needed and what is best. This seems unwarranted in the light of recent experience, certainly in relation to rural areas. Second, it is assumed that there is little room for technological innovation or improvement and that such an item is of low priority.

The stance that is adopted at the international and often at the national level also, is that "we have the technology and know-how and we understand what is needed--give us the money and the backing, and we will see that the job is done". Admittedly this is somewhat of a caricature, but it captures the essence of a position that has considerable merit and has proved impressively successful in the industrial nations and in some metropolitan areas in developing countries. It seems unlikely to be successful, however, in rural areas and small communities in the developing countries where the major need is now to be found. It is also less appropriate for the urban peripheries.

The most frequently cited reason for the lack of more rapid progress in achieving water supply and sanitation improvements is the insufficiency of national funds allocated to this end or the lack of priority accorded in national plans. Such an assertion reflects only one aspect of the situation however, and can more accurately be considered in relation to the technology commonly employed. The more costly the engineering methods and equipment used the smaller the number of people that can be served for a given expenditure. Hence a trade-off situation exists between funds available for investment and the cost of the technology. At the present time the technical solutions used are expensive and the available funds are low in relation to the need. Under these circumstances severe limits are imposed upon what can be achieved. The cry for more funds may reflect a judgement that it is easier or more practicable to increase financial resources than to lower the cost of technology.

Reasons for this judgement are not far to seek. Allocation of more funds can seemingly be done quickly at the stroke of a pen. It is known that the available technology works and has brought dramatic improvements in health to large populations and has reflected credit on those responsible for its design and operation in many industrial nations. By comparison research and development of new low-cost technology or an adaptation of existing technology is likely to take more time. Furthermore, it costs money that might otherwise go directly into project planning or capital works. Also the results may be disappointing or negative, hence to direct money to technological research and development is risky, whereas to invest in what is known and tested seems much safer. To risk the development and application of new low-cost technology may threaten the reputation of the innovator and undermine the credibility of field operations. Conventional technology may be inappropriate because it costs too much but adapted low-cost technology may be unacceptable because it lacks prestige and fails to confer a sense of status or importance on the operators and managers. Insofar as low-cost technology is feared to involve a reduction in safety margins or a greater risk of spreading disease, added cause for caution is found.

In spite of these fears many engineers grappling with water supply and sanitation problems in trying circumstances would be anxious to experiment with new techniques and equipment if given more backing and encouragement. Often, however, planning and design operations leave little or no room for innovative approaches. Budgets are tight and allow little possibility for experiments that are meant to develop or test new ideas. There is often little more a field engineer can do than pull out his drawer full of standard and conventional techniques knowing that there is an accumulated wealth of experience to back up his decisions, and an international supply of the equipment he will need to purchase.

High cost is not the only way in which technology can be inappropriate. As discussed earlier it should also be compatible with local or user needs. The evidence suggests that much of the technology presently available is not only expensive but also imposes high demands for operation and maintenance on local organization and skills. It is so demanding in these respects that the population in many rural areas is unable to make use of the technology available. When improved systems are built they are subject to frequent failure. We estimate that as many as one third of the village systems constructed in the last two decades are completely inoperative and that another third function defectively. It is not uncommon to see modern water supply systems abandoned while people resort to the traditional methods and sources.

Technology can also be inappropriate if it uses large amounts of capital to perform functions automatically in an economy where capital is scarce and labour is plentiful. It can also require the use of limited amounts of foreign exchange for the purchase of equipment and spare parts when local materials are present that might be developed and put to use, including the development of local manufacturers.

A reason for the allocation of insufficient national funds, therefore, can stem from a concern to use limited resources wisely and not to squander them on extremely expensive technology that will lead to the creation of systems that are difficult to operate and maintain; subject to too frequent collapse; replace local labour with imported machinery and equipment; and serve as a continual drain on foreign exchange without helping to build up local capacities.

Viewed in this light the failure of national governments to accord high priority or to allocate funds in sufficient quantity can be seen as a victory for common sense. Only as more appropriate technology is made widely available and is accepted by both the engineering profession and the users, will substantially larger investment seem warranted.

CRITERIA FOR APPROPRIATE TECHNOLOGY

What criteria would more appropriate technology have to meet? A few of the more important ones have already been suggested. Others relate to the capacity of the local managerial organizations and the needs of the users. The technology should be suitable for local maintenance and operation by relatively unskilled manpower. If it is to be compatible with local values and preferences it probably should be capable of incremental adoption and improvement. Our field experience suggests that difficulties are prone to arise when attempts are made to take a community from an unimproved water supply to a very modern and sophisticated system. It might be better therefore to allow for gradual and incremental change that can proceed at a comfortable pace according to user demand. We confess, however, to considerable uncertainty on this score and think that there is need for research into ways of fitting the technology to local preferences and needs. We have little knowledge or experience of how this might be done.

Another characteristic of observed projects is that they seem to lack a strong diffusion capacity. Improvements that are made in one village with outside help do not spread contagiously to other villages. There are no doubt many good reasons why this is so. It seems however, that a criterion for appropriate technology would be its capacity to produce a contagion effect.

On the basis of this diagnosis ten criteria for the development or selection of technology are suggested. This is by no means an exclusive list, but it contains those which an informed concensus of experienced personnel would accept plus some others that represent our best judgment at this time.

The water supply technology chosen (or developed by research) for rural areas and small communities should:

1) Facilitate significant improvement in quality and quantity of service without necessarily seeking to obtain the near-perfect.

2) Be low in cost; as low as possible without jeopardizing the effectiveness of the improvements sought.

3) Facilitate operation and maintenance by local populations and users without demanding a high level of technical skill.

4) Make as much use as possible of locally available materials, and rely as little as possible on imported supplies, spare parts and equipment.

5) Make use of locally available labour, including unskilled labour and not try to replace labour with capital equipment unless it is clearly imperative to do so, e.g. when local labour is scarce.

6) Encourage the growth of local manufacture to supply the need for equipment and parts, under the leadership of local entrepreneurs.

7) Be compatible with local and user values, attitudes and preferences.

8) Provide opportunity for incremental adoption and step-by-step improvement.

9) Have a capacity for producing a contagion effect and so diffusing to other communities and individuals.

10) Facilitate community involvement and participation.

Since there is little technology that meets these criteria, and that which does tends to be inaccessible we may legitimately conclude that there is a role here for research and development. How should such research and development proceed and how should it be organized?

RESEARCH AND DEVELOPMENT NEEDS

If we recognize that we do not have the sort of technology that is needed to do the job how can the more appropriate technology that fits the local needs of the developing countries be created and brought to bear? Clearly this requires much research and development work to be undertaken that is not presently being supported. This is not to say that there is no research and development work in the water supply field, but what is done overwhelmingly takes place in the industrial nations and is directed towards their particular set of problems. The technology produced tends to be too expensive, too demanding in terms of its operational and maintenance requirements, difficult to manage and does not meet the other criteria specified above. What work is done in developing countries tends to be imitative of that which is done in the industrial nations.

Even though a case can be made for some original research and development work on the technology of water supply this does not mean that much appropriate technology does not already exist. This however is generally not made available and accessible to the potential users. There is therefore also a need for the assembly and testing of existing technologies and the dissemination of information about it as well as steps that are needed to make it accessible. This might extend not simply to the dissemination of information but also to the organization of local manufacturing capacity.

Research and development activities of this kind might be added to those already underway in the industrial countries, but I believe it would be much better if this were to be done in the developing countries themselves. This would contribute, not simply to the solution of the present generation of difficulties but would help to establish a research capability that could contribute over many years to an incremental improvement programme.

In the agricultural field we now have functioning the International Consultative Group for Agricultural Research, consisting of international banks, assistance agencies, governments and private foundations. This year it has raised 33 million dollars which goes mainly to the support of the International Agricultural Research and Training Centres, the first four of which were originally established by the Ford and Rockefeller Foundations. I have in mind the International Rice Research Institute in the Philippines, the International Maize and Wheat Improvement Centre in Mexico, the International Institute of Tropical Agriculture in Nigeria and the International Centre for Tropical Agriculture in Colombia. To these four international research institutes in the agricultural field other more specialized institutes are now being added, for example, the International Crops Research Institute for the Semi-aird Tropics in Hyderabad and the International Potato Centre in Peru. I believe a similar arrangement would be highly profitable in the water field.

We might best begin with the most urgent need, that is, for potable water supply. An International Centre established for such a purpose could act as a focus for research and development, training and the dissemination of information on appropriate technologies and related activities for water supply in the developing countries especially in relation to rural areas and small communities. Such an institution should have a degree of independence but must also be prepared to work with the existing agencies at the international level and with the national governments in the developing countries.

OTHER WATER RESOURCE AREAS

I have so far dealt chiefly with the problem of potable water supply, and the difficulties encountered here have their equivalents in other areas of water resource technology. I need to mention only a few of these for the picture to become clear.

The achievement of expanded agricultural output and livestock production by the augmentation of water supplies has been marred by the creation of new risks arising from unforeseen ecological and environmental consequences. A well-known example is the destruction of irrigated land by salinization. In Pakistan particularly land supporting a low density of livestock or low crop yields has had its productivity dramatically increased by the provision of irrigation water, and then has been virtually destroyed by the increase of soil salinity, and has become no longer capable of supporting even the meagre production of which it was capable before irrigation.

The expansion of irrigated acreage brought about by the High Aswan Dam has been partially negated by the lack of fertility replenishing flood waters in other areas and the consequent need to use more fertilizers. This is making the Nile Delta vulnerable to international fluctuations in the price and availability of fertilizer to a degree that has not obtained before. The provision of improved water supplies for livestock in the Sudano-Sahelian region appears to have helped to bring about an expansion of the livestock population with the consequent over-grazing of the range, and increased vulnerability to drought conditions now making itself dramatically evident. More caution is needed in the utilization of technology which will bring obvious short-run benefits but which may create new or increased vulnerability to fluctuations in the international economy or the state of nature.

The construction of flood control dams and the building of levees, dikes and other engineering structures can prevent the occurrence of many damaging floods. It is usually possible to show that the damages prevented exceed the costs of flood prevention works. Experience in the United States, however, has been that flood damages have gone on rising and that the catastrophic component of flood losses has risen more rapidly than overall losses. The most costly national disaster in the nation's history occurred in June, 1972, with the floods of Tropical Storm Agnes and much of the damage resulted from the overtopping of flood protection works. We are now trying to correct the oversights of the past by moving away from the flood control concept to a more comprehensive policy of flood damage reduction, including flood plain management, flood-proofing, emergency measures and insurance. At the same time, however, we still encourage, directly and indirectly, the adoption of flood control technology in the developing countries which will expose them to a repetition of our experience. Under this approach, the more successful the country is in its development activity, the more it is likely to be building up potential disaster situations in the future.

CONCLUSION

If there is a common thread to these cases it is that efforts have focussed on getting the technology on the ground and in place and functioning much more than on how it will fit into the local conditions and how the users and managers of a different society will respond to it.

The technology that can be transferred most successfully is that which can be isolated almost completely from the conditions prevailing in the host country or location. Most spectacularly this applies in the international commercial aviation field. Capital investment in equipment is high and a relatively small number of highly trained personnel are required for operation and maintenance. The air transport system can function almost independently of local conditions. It does not affect the lives of the overwhelming majority of the people, and it does not penetrate significantly into the local culture or society. It is a successful extension of advanced industrial technology into the developing countries, associated in the minds of many with the established economic order, and symbolizing for some the hegemony of the metropolitan powers.

Water resources cannot be successfully handled in similar fashion. The management and development of water resources is a process which cannot be so effectively isolated from the local culture or society. Indeed attempts to develop water resources in a culture-proof fashion are self-defeating. The object of water resource development is not to put in place some effectively functioning water supply or flood control or irrigation system. It is to move towards the social and economic objectives set by each country.

NOTES

1) Bernd H. Dieterich and John M. Henderson, Urban Water Supply Conditions and Needs in Seventy-Five Developing Countries. Public Health Paper No. 23. World Health Organization. Geneva. 1963.

2) World Health Organization, Twenty-Fifth Health Assembly. Community Water Supply Programme. Progress Report of the Director-General. Document A25/29. Geneva. April, 1972.

3) Document A 25/29. Geneva. April, 1972.

EVOLUTION OF MODELING IN WATER RESOURCES PLANNING[1]

by

Frank E. Perkins[2]

Introduction

It is generally acknowledged that in highly developed countries of the world mathematical models are beginning to play an important role in water resources planning. The same comment may also be applied to water resources planning in the less developed countries of the world when that planning is carried out by leading consultants from the developed nations.

The rationale for employing models and the potential benefits which their use offers have been well defined by Dr. Nathan Buras, a leading water resources engineer and engineering educator in Israel in the following comments before the International Symposium on Mathematical Modeling Techniques in Water Resources Systems held two years ago in Ottawa, Canada. Dr. Buras stated:

> "The rapid increase in the world population and the rise in the standard of living generate an ever increasing demand for water. In order to service large population concentrations, large systems have to be built and operated. These large and often complex systems may become even more complicated as the development and utilization of regional water resources approach the limit of the available supply. Furthermore, such development has an impact on the environment, affecting, to one degree or another, the various ecological systems within the region. To cope with such a situation, more exact planning of water resources systems is necessary.
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> The complexity of water resources systems stems from the fact that their components arise from the natural (physical and biological domain) as

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1 Paper presented at the MIT Symposium on Strategies for AID Programs in Selected Areas of Science and Technology, Endicott House, Dedham, Mass., 23-25 April 1974.

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well as from the social (economical, institutional) domain. The analysis and understanding of these complex systems necessitate, among others, the construction of mathematical models which express the multi-disciplinary aspect of water resources development, utilisation and conservation. Such modeling and analysis have been advanced mainly due to three major factors: a rational conceptual approach (systems engineering), effective methods of mathematical analysis (operations research), and computational facilities (analog, digital and hybrid computers).

Finally, one should remember that the planning process has any validity only if it looks forward into the future, but it is based on data which represent the past. Mathematical models are the only means known to us today for linking the two in an effective manner."

In spite of the potential benefits offered by mathematical models and their acknowledged use in some planning efforts there is a considerable gap between those who have a sophisticated understanding of the role which models can play and those whose knowledge in this area is merely superficial. This gap is cause for concern especially in situations where such models may be used in guiding the planning and management of water resources developments in the less developed countries, countries in which the investments resulting from such planning are likely to have major impacts on their future.

Because of this concern, I propose to speak to three issues. First, I shall make a brief commentary on the several steps which I feel have characterized the historical evolution of the use of mathemat cal models. Through this I hope to show where we have been, where we are now and where we hopefully are headed relative to their acceptance and application in the future.

Second, I would like then to state what I feel should be the proper role for mathematical models in water resources planning; a role not always successfully achieved, but one which is to be desired.

Finally, I will attempt to relate these first remarks to the particular concerns of less developed countries. In this regard I shall raise two questions: the first concerning the allocation of scarce human resources to development of mathematical models; and the second, related to possible misuses of mathematical models in these countries. No attempt has been made to consider specific applications of models. The reader interested in such illustrative examples is directed to the collection of case studies in a recent book by deNeufville and Marks.[3]

In preparing these remarks I have proceeded from certain assumptions which I feel to be true but which I have not attempted to document in any rigorous way. These assumptions include the following:

1. The pressure for rapid and large scale development will continue to grow within the less developed countries.

2. An important element of this development will center around the management and planning of the water resources of these countries.

(As an aside it should be noted that my experience in any of these countries is of a sufficiently limited nature that I am not competent to judge what form this development should take or even how the planning should be done. However, grandiose schemes such as the recently proposed plan to tie together the major rivers of India, or the massive projects planned by the Mekong River Commission, are indicative of present responses to the pressures for development).

3. The two most important new elements in water resources planning methodology are:

   i) The principles embodied in multi-objective investment criteria.

   ii) The use of mathematical models.

4. Pressure exists or will be generated to employ these new elements in planning for water resources development in developing countries.

(In this regard I would note the incorporation of multi-objective investment principles in the document UNIDO Guidelines for Project Evaluation which forms a basis for much of

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[3] deNeufville, R. and D.H. Marks, Systems Planning and Design, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1974.

the world's planning efforts. Further, I would note that on a tour of water resources planning agencies in Asia last year and from more extensive experiences in South America I found considerable evidence to indicate that pressure exists to make more extensive use of modern modeling techniques even in the face of considerable skepticism over their value).

5. The use of multi-objective investment principles and mathematical models are inexorable related. Therefore, the clear pressures to employ the former will lead directly to pressure for employment of the latter.

In the face of these pressures for development and the resultant pressures for the use of mathematical models, I feel it is appropriate that we examine the evolution of these models and their potential role in the planning process.

The Evolution of Mathematical Modeling

The evolutionary process which the art of mathematical modeling has undergone can be described in terms of methodology, problems modeled, or the role and acceptance of models. The methodology of mathematical modeling is frequently described in terms of the mathematical techniques which have been employed. One can therefore characterize the evolution in terms of the introduction of linear programming, dynamic programming, and later, various non-linear programming techniques. Similarly, one can look at simulation models which for physical systems at least were initially characterized by one dimensional models. Another way of characterizing by methodology would be to examine the size of model which could be handled at various points in time. One decade ago, linear programming models having 100 decision variables and 100 constraints might have been considered large. Today those figures are more typically measured in several thousand decision variables and constraints. Similarly, the allowable flexibility and detail of simulation models has increased by at least two orders of magnitude over the past decade.

A second method for viewing the evolution of models is in terms of the problems which are being modeled. Initially in the evolution of models, models were thought of for modeling the behavior of physical systems. This was probably a direct outgrowth of the more familiar application of physical models in water resources planning. The Harvard Water Program and other similar programs of the early 1960's introduced the idea that economic factors as well as physical factors could be included in the modeling process. Today we find increasing attempts to incorporate social, legal and political factors into the modeling process as well. Hence, the nature of the problems being modeled has evolved from models of the purely physical system to attempts today to incorporate all of the major social, economic, political and physical factors.

A third method of characterizing the evolution of models is in terms of the role they play in the planning process, and their acceptance by the planners in that process. This is the basis on which I would wish to comment in more detail on the evolution of models.

On this basis the evolution of models can be traced back as far as one might desire. For example, ancient man understood the effects of the moon on the tides, and used his ability to predict the phases of the moon as a basis for predicting the nature of the tide. In spite of the absence of a digital computer and sophisticated mathematics this was an early application of modeling procedures in water resources planning. Similarly, the ancient Egyptians were able to make use of a variety of indicators to determine whether they should expect a large or small flood on the Nile. However, I do not really wish to carry the evolutionary process back to that extent. Rather I will start with the period which was introduced by the Harvard water program less than 15 years ago. That program can hardly be characterized as the sole originator of modern mathematical modeling techniques. However, the impact of the program was so great, and the consequences so far reaching that it is appropriate to choose this as a starting point. Since that time we have rapidly passed through several stages in the evolutionary process. These stages are clearly not separate and distinct, rather, they overlap to some extent, and some continue for a longer period than others. Nonetheless, I feel that it may be useful to examine the evolution in terms of these stages or phases.

The first stage was a more formal understanding of the planning process and the subsequent recognition of the potential that mathematical models had to offer for water resources planning. This first stage I would equate with the initiation and early development of the Harvard Water Program. The second stage consisted of the implementation and publication of a few demonstration examples which served to illustrate the potential of the mathematical modeling techniques. These initial examples are characterized, for example, by the examples published in the Harvard Water Program publication, Design of Water Resources Systems, with which so many of you in the audience are familiar.

The third stage which rapidly followed consisted primarily of research and development on the methodologies of mathematical modeling and was characterized by the publication of large numbers of papers which dealt with the details of new methodology and which tended to ignore the very real problems posed by the practical aspects of real-world water resources planning. This, in turn led unfortunately to the fourth stage which I have chosen to call the panacea stage of mathematical modeling. This is the period when unsophisticated and sometimes naive investigators jumped on the mathematical modeling bandwagon and proceeded to make unreasonable and unjustifiable claims for the potential and power of the new mathematical modeling techniques. During this period the words "optimization" and "optimization model" were interpreted as meaning that truly optimal solutions to water resources planning problems could in fact be obtained simply by application of an appropriate modeling technique. This period was followed by early attempts at somewhat realistic applications. I have chosen to call this the "we can do it" stage because many of the publications during this phase of the evolution seem to be more concerned with demonstrating that some particular modeling technique could in fact be applied to a water resources planning problem rather than to a consideration of the solution and needs of the problem itself.

As the limitations of these efforts at modeling became obvious, and as experienced planners confronted these limitations we entered a stage of justifiable skepticism. At this point many consultants and planners concluded that the unexpectedly high cost of developing models and the unexpected limits of their applicability made the potential benefits of mathematical models highly questionable. The research and development in this stage dealt less with the methodology of mathematical models and more with their application. This was the period in which we began to develop a recognition of the limitations of these models and undertook to understand more clearly how in spite of these limitations an appropriate role for the power of mathematical models might be developed.

From this stage, which is still very much in existence, we enter the present stage in which practicing engineers, planners and government agency personnel are gradually accepting models as natural and useful tools, and are beginning to develop an understanding of their proper role in the planning process.

It is interesting to note that the understanding of this proper role was apparently clearly understood during the first stage of the evolutionary process. The early literature of mathematical modeling in water resources planning clearly defined the proper role, the potential, and the limitations of mathematical models. It is interesting to speculate on why it has taken us 15 years to understand and appreciate the ideas which were advanced during this first phase. The explanation may lie in the fact that much of the ensuing research and development on mathematical modeling was done by individuals with relatively limited experience in the practical aspects of real world planning and management. Hence, the 15-year delay time may have been necessary for the university researchers to truly appreciate the complexity of the planning problems with which they were involved.

I believe that we have begun to close the gap between university research and the needs of practicing engineers and planners. The closing of the gap has lead to a gradual, but I believe successful acceptance of these modeling procedures by practitioners. At this stage of development the application of mathematical models is a blend of art and science. While the artistic components will always remain I believe that we are now entering a stage in which the science of the application of mathematical models to real world problems is being developed. This stage in the evolution will, I hope, lead to a better understanding of the limitations of mathematical models and will provide a more rational basis for the application of particular modeling techniques in any given situation. This stage of the evolution requires and does in fact involve a close interaction between those who are carrying out research on these modeling techniques and those who are responsible for their application. If successful I believe that this stage of the evolution will result in a general acceptance of modeling techniques through out the engineering and planning professions which will then allow us eventually to enter a period of refinement and maturation of the field of mathematical modeling in water resources planning.

In these preceding remarks I have implied at several points that the role of mathematical modeling in water resources planning has not always been properly understood. The fact that we have had to pass through the panacea stage and the stage of justifiable skepticism is directly attributable to this lack of understanding. As a result I would like to comment further on what I feel is the proper role of models in the planning process.

Role of Mathematical Models

In considering this role it is useful to review certain characteristics of the planning process and of models. Taken together these characteristics define what I feel to be the proper role for models.

For those who are intimately familiar with such models and who have developed a philosophy with which to guide their application to real-world problems, these comments are undoubtedly redundant and over-simplified. However, for those who do not have the requisite modeling background or who still view such models as a collection of techniques which are not integral to the planning process, it is hoped that the review will be useful.

One of the most significant characteristics of planning is that it is a dynamic process and as such may be characterized in terms of a set of activities which take place over time and which interact through the transmission and feedback of information. It is the function of these activities to convert that information into forms from which a set of decisions, i.e., plans, can ultimately be produced. At all stages of this process questions arise which, if properly posed and adequately answered, will lead to plans which in some sense are better than if the questions had not been posed or adequately answered. One view of the modern planning process is that the concepts of multi-objective investment criteria will lead to the posing of better or more appropriate questions in the planning process, and that the use of mathematical models will lead to better answers to these questions.

Thus, in very simple terms the role of models may be viewed as that of tools from which to derive answers to well posed questions about the performance or behavior of the system which is being planned. However, because of the dynamics of the planning process it may happen that the answers derived from the models will suggest that the original questions were not well conceived and must be reformulated. Hence the role of models is really double edged. They are used to produce information which may be fed forward to aid in decision making (i.e., plan formulation). With equal value, they may produce information which is fed back to aid in redefining the problem.

A second essential point concerning the role played by models in the planning process is that the information which they provide must be quantitative and in sufficient detail and accuracy as to provide real guidance to the decision maker. There are three key words in this statement. The first of these is the word "quantitative". This does not mean that the model must produce numerical results, but its outputs must provide a basis for decision making, and this is possible only when the results have some measure or rank associated with them. The second key word is "sufficient". There is a natural tendency to use models to produce answers which are in as great a detail and accuracy as possible, especially when a model which does so is readily available. However, as in all planning and design, a balance must be struck between the needs of the problem at hand and the resources which are available for its solution.

Finally, operation of the model should provide "guidance" to the decision maker. The role of the model is not to do the planning or to replace the planner. Nor is the role of models to provide completely precise answers to the questions which have been posed. Rather, the model should produce information which will validly guide the thinking of the planner concerning the decisions which he is called upon to make.

The preceding points concerning the role of models are elementary and intuitively obvious. They are included here because of my observation that they are frequently overlooked or ignored. Commenting on this problem in an excellent summary of the state of the art of model use in water resources planning, Marks[4] has noted:

> "The fact that there has been difficulty in implementing results stems mainly from two problems. In some cases researchers have addressed themselves to problems that interested them, not the people who had to make the decision. In other cases, the modeling process was seen by the analyst as synonymous with the decision process. This is just not possible for there is no way to capture the complexity of the decision process in a model and the analyst must be content to provide information which helps illuminate for the decision maker the tradeoffs available in the decision process."

In considering the role of models it is also useful to ask why one should plan to use models at all. The answer is

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[4] Marks, D.H., "Models in Water Resources," chapter in the book, A Guide to Models in Governmental Planning and Operation, to be published by the U.S. Government Printing Office, 1974.

quite simple. In all but the most trivial planning problems we typically deal with systems which in many senses are complex, whose behavior (past or future) is not completely understood and for which apparently important data are not available. Planners are called upon to determine how such complex systems should be operated and/or altered to achieve a desired set of objectives. For systems of even relatively low complexity the number and nature of alternatives, interactions, responses, and so forth which are possible far exceed our capacity to enumerate and evaluate completely, and leave us hesitant to base our decisions solely on intuition or past experience.

Hence, we turn to models because of their potential for performing three valuable functions. These are:

1. Amplification -- When properly used, models can amplify our available knowledge of the behavior of complex systems. Models do not produce new information, however they permit the extraction of greater amounts of information from our existing data base. In this sense they increase our understanding of the problem under study and of the options for dealing with it.

2. Organization -- One of the biggest problems encountered in planning is to represent and display in simple terms the numerous characteristics of complex systems and proposed plans. Models serve an invaluable function in providing a basis for such representation for actually carrying out much of the computation which is required for this organization.

3. Evaluation -- Models frequently can be designed to incorporate measures of performance of the system under study (as contrasted with more commonly employed measures of behavior) and may therefore be designed to produce comparative evaluations of performance. Optimization models always serve this function in that they compare the performance of various alternatives and identify that which is best in some sense.

There are many other useful views of the functions served by models which differ slightly from that presented above. Regardless of just how these functions are categorized, the essential point here is that models are essential tools for supplementing the planner's judgment, intuition and past experience. Models can in no way be viewed as replacements for these valued human skills. There remain too many limitations on our ability to model for this to be an issue of much serious concern.

It has been my observation that at least two erroneous beliefs are prevalent among planners and decision makers who have not yet become sophisticated in their approach to the use of models. These modeling myths can create difficulties in trying to sell the use of models where they are not currently employed, and in trying to present the results of models to an uninformed decision maker.

The first of these modeling myths is that there exists a single model which will completely solve the planning problem. It is doubtful that only one model is required. My experience, and that of many others, suggests that a hierarchical family of models is likely to be of greatest value in the planning process. Even then, no set of models will completely solve the problem; rather, as noted earlier, the models can only provide guidance as integral components of the planning process.

A second myth is that models somehow require more data than other procedures or more data than can possibly be made available. The myth arises from the fact that some particular new model may in fact require more data than a previously existing procedure or more data than is currently available in a particular planning exercise. However, these deficiencies are not inherent characteristics of models but only of the particular application. When properly conceived, models are designed to operate on the existing data base to produce the greatest possible amount of information from the data. When a particular model demonstrates that the data are inadequate to make an intelligent decision, the deficiency lies not with the model but with the data.

During a trip to several Asian countries last year I found both of these misconceptions over the role and utility of mathematical models to be widespread among water resources planners.

One final point should be made about the potential role of models.

The process of developing a model necessarily implies a process of abstraction from the real world. The manner in which this abstraction is performed and the level of detail which is retained will control in large measure both the fidelity and cost of the model. Often, although not always, increased fidelity is purchased by increased detail and cost. However, since the evolution of modeling has not yet reached the point where rational criteria for comparing and choosing among models are well-established, considerable judgment and experience is required at this stage of the modeling process, and it is here that the "art" of modeling is more apparent.

The need to make a conscious choice among the many levels and types of model which are available is often overlooked, yet the decisions made at this stage greatly influence the remaining steps of the process. At the very least, one should constantly be prepared to question the appropriateness of the particular model which has been adopted and be prepared to alter the model whenever there appears to be good reason to do so. One should never be misled into thinking that the presence of a working model guarantees that all of the relevant characteristics of the modeled system have been adequately accounted for. Hopefully, the model reproduces in a reasonable way those properties which are essential to the particular problem under study, but the necessity to abstract from the real world always leaves unresolved questions about the completeness and vaildity of the results which it provides.

This point has been well-stated in an interesting paper by Toebes[5] who writes:

> "Suppose that it were possible to build a mathematical model that included all imaginable components, its analysis would be wasteful since only components that add or detract materially from the objective are relevant. Thus the problem is to first create a system that is simple but yet representative of a real system. This is a 'chicken-and-egg' problem because 'real' implies relevant, whereas relevance must be ascertained by testing a system that one does not have. In practice then one must conceive tentative alternative systems. This stage is critical since overlooked opportunities cannot be recovered no matter how refined subsequent analyses may be. It is this stage that requires most of the creativity that is normally associated with design for open-ended situations. It is this stage, furthermore, which shows that there is no immediate, deterministic progression from systems objective to design and from design to analysis."

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[5] Toebes, G.H., "The Role of Systems Simulation in Water Resources Development," Proceedings of the Thirteenth Congress of the International Association for Hydraulic Research, 31 August - 5 September 1969, Vol. 1, pp. 447-455.

Hence there is clearly a difficult trade-off which must be made in determining the appropriateness of various modeling techniques for a given situation. Failure to understand and appreciate these tradeoffs is probably the major reason for failing to achieve the full potential of mathematical models.

Relation to Developing Countries

It seems clear at this point that mathematical models will be used with increasing frequency in the developing countries of the world. There are several reasons for feeling so certain about this prediction. First, and hopefully foremost, is the realization that the complexity of the development problems facing these countries demands that the best possible planning procedures be employed. When properly understood and applied, mathematical models do have the ability to assist in this process to an important degree.

Second, there is a pressure to employ models which derives from the wish to adopt what are perceived to be the most advanced techniques of the developed nations. Part of this wish is a reflection of the assumption that the latest, most advanced techniques must obviously be the best, and part is the natural tendency to want to appear on a technological par with the developed nations.

A third reason for assuming that mathematical models will be used in the developing nations is based on the historical observation that the U.S. (among others) has in fact been an exporter of water resources planning technology. Throughout the developing countries, particularly in the Far East, one finds extensive evidence of the influence which the Bureau of Reclamation and Corps of Engineers have had on the planning and analysis procedures currently employed in the U.S.

It is clear that all three of these mechanisms are presently operating and it is likely that they will continue to increase the attempts by developing nations to employ mathematical modeling techniques in their water resources planning activities. It has already been established, based on experience in the U.S., that these attempts will likely pass through an evolutionary process which is potentially fraught with some disappointments and failures. Hopefully it will be possible to benefit from the maturation process which we in the U.S. have already experienced, and that many of our misconceptions and false expectations can be avoided. However, I tend to be somewhat pessimistic in this regard and feel that it may be necessary to replicate the U.S.'s evolutionary process described earlier, albeit at a faster pace and without the same magnitude of difficulty. The extent to which the process can be carried out smoothly and our own mistakes avoided depends on the extent to which those who have experienced this evolution are willing to document and share their experiences with those whose experience is less extensive. My pessimism in this regard stems from the apparent hesitancy of the "experts" to discuss failures along with their successes in the general literature and at open forums.

I have also tried to make clear that mathematical models have a tremendous potential for assisting in the process of planning for development. The evolutionary process leading to their mature utilization can and probably will take place. There are, however, two problems which should be of real concern in the special circumstances encountered in developing countries. These are:

1. Misallocation of the limited human resources for planning

2. Potential use of models to legitimize rather than analyze proposed courses of action.

Each of these are discussed briefly in the remaining paragraphs.

It is generally acknowledged that the developing countries (with a few notable exceptions) will continue to experience a serious shortage of highly trained technical personnel. Even in those countries, such as Korea, where a successful transfer of water resources planning technology has already taken place, the transferred technology is that of two decades ago and has not provided large numbers of people trained in the application of modern modeling techniques. A limited number may have received education in the theoretical underpinnings of such techniques but the gap between theory and application is not easily bridged. Given the nearly total absence of personnel experienced in the application of new techniques and the serious shortage of more traditionally trained planners and engineers it has been argued that modeling techniques should be avoided as causing a too costly dilution of the available talent; isntead, efforts should be concentrated on attacking the pressing current problems with existing tools.

This argument has considerable appeal, in the short run at least. Proponents of the argument state that it will allow them to wait for further evolution of modeling techniques, will provide users with more certainty of their value; and will therefore permit a better use of models when they are eventually adopted. Furthermore, they continue, such a decision will permit the limited available talent to concentrate on immediately useful activities.

Running counter to this view is the observation that the pressures to use models are real and will in many cases prevail. In this case it is clearly better to take an active part in the ongoing evolution of these models rather than trailing farther behind in which case local planners could easily become totally dependent on outside experts (or even worse, local amateurs) who use their knowledge of modern methods to establish control over the planning process.

The second area of concern in this issue relates to the potential use of models to legitimize a proposed plan. In the ideal case models are used to evaluate alternatives and to clarify the development issues which are implied by each alternative. Experience indicates that mechanisms designed to illuminate issues may often be employed in such a way as to achieve just the opposite result. This is not to imply that this reversal of objectives is necessarily done in an intentionally malicious manner, but regardless of intent, this negative result does occur.

An excellent example of this phenomènon is found in the use of environmental impact statements which are now a required part of much of our planning in the U.S. On the local community level at least, (and possibly on larger projects as well) there is evidence that the impact statements are used merely to justify a proposed course of action rather than to establish clearly the potential impacts of the proposed action and its logical alternatives.

With highly sophisticated computer models employed in areas where there is little or no resident understanding of the power and limitations of such models the potential for misusing the models is extremely high. This danger has been clearly voiced by Daniel Bell, Professor of Sociology at Harvard University. Writing in the June 1969 issue of Technology Review on the subject, "Knowledge and the Balance of Power", Professor Bell warns against decision making by a technological elite who may fail to understand the need for political and economic rationality along with a technical rationality. He writes:

> "This, then, is the balance of knowledge and power: to spell out the technical components and the dimensions of cost; to widen the options and to specify the moral context of choices so

> that decisions may be made more consciously and with a greater awareness of responsibility. It is in the interplay of the technical and the moral that rationality has to be sought."

In order for this interplay to take place in the developing countries and thus avoid decision making solely by the technological elite it will be essential for planners in these nations to develop a deep understanding of mathematical models and their proper role in the planning process. Models will be used; the only real question is whether the developing countries can prepare themselves in such a way that this use will be certain to be for their benefit.