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PRE-TEST FOR MANAGING ENERGY AND RESOURCE EFFICIENT CITIES:

STATE-OF-THE-ART REVIEW

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Coopers
&Lybrand

FOREWORD

The state-of-the-art (SOTA) literature review covers several areas or sectors essential to the "management of energy and resource efficient cities":

- Land-Use Planning
- Transportation
- Energy and Electric Power Systems
- Water and Sewer
- Solid Waste Management
- Building Design and Materials

The report reflects considerable research and interviews with sector specialists and the results of workshops held in the City of Tacloban (Philippines) October 22-23, 1981, and in Washington, D. C. December 10-11, 1981.

The report was produced under the overall direction of Lawrence Revzan, project manager, who also wrote the chapter on Land-Use Planning. D. Andrew Goddard, author of the chapters on Water and Sewer and Solid Waste Management, has played a critical role in production of this report and in the on-site assistance provided to the City of Tacloban. Hollis Gillespie wrote the chapter on Building Design and Materials and coordinated C&L's literature search efforts and preparation of a comprehensive, annotated bibliography. P. Patricio Crespo assisted in the literature search and report preparation. Overall guidance was provided by Zoltan Pazmany, partner, and Robert Craver of C&L's international group.

Coopers & Lybrand was assisted by several outside consultants in the preparation of this report. Primary authors included George Savage (Energy and Electric Power Systems) of Cal Recovery Systems, Inc. and David Whitman (Transportation) of Systan, Inc. Special thanks are due to Luis Diaz, President of Cal Recovery Systems, Inc., who participated in the Tacloban Workshop and provided valuable assistance to the City of Tacloban in

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I. INTRODUCTION

I. INTRODUCTION

OBJECTIVES AND BACKGROUND

The objective of this report is to present a state-of-the-art (SOTA) review of literature covering a variety of areas where intermediate-sized cities in developing countries can conserve energy and other resources. The report represents one end-product of a project entitled "Pre-test for Managing Energy and Resource Efficient Cities," sponsored by the office of Urban Development, Bureau of Science and Technology, U.S. Agency for International Development (S&T/UD, USAID).

The report is intended for use as a "field guide" by officials of national governments and intermediate-sized cities (population in the 75,000-250,000 range) in developing countries. It was developed in conjunction with the USAID Mission in the Philippines, and the city of Tacloban located on the island of Leyte in the Eastern Visayas, population 103,000, which served as a demonstration city. A companion volume entitled "Tacloban Situation Report and Preliminary Strategy" has been prepared under a project agreement between the city of Tacloban and Government of the Republic of the Philippines and the USAID Mission in the Philippines. The Tacloban strategy is the result of a careful analysis of the problems faced by the city in conserving energy and other resources and the application of approaches suggested in the SOTA review to those problems in a systematic, cost-effective way.

Each chapter of this report contains a general discussion of the topic, a review of specific tools utilized to solve resource conservation problems, and a summary of case study applications that may be applicable to intermediate-sized cities in developing countries. A list of footnotes and list of key references are provided at the end of each chapter, with extensive documentation in the text. The chapter on Building Design and Materials also

contains a Glossary covering technical terms that may be unfamiliar to the lay person. Appendices provide a comprehensive bibliography and annotations of key references.

The Project Identification Document (PID) prepared by USAID notes the increasing urbanization process taking place in developing countries and the strains this process will place on a variety of locally-based resources. The sectors selected for review were felt to be the most critical to the future of intermediate-sized cities and those over which city officials and private sector interests could exert influence to improve efficiency in utilization.

The six sectors selected for intensive review are linked together systematically. Land as a physical resource is directly involved in the majority of resource allocation decisions, and land-use planning represents a technical field utilized by local units of government to rationalize the process of land consumption and the interrelationships among land uses. Transportation, water and sewer, electric power systems, and the collection and disposal of solid waste are all major consumers of energy and interact with each other as well as the land-use sector. Selection of building materials is an important element of energy conservation in residential commercial, industrial, and institutional structures. The recycling of solid wastes and the efficient design of infrastructure support systems all provide opportunities to conserve resources and energy.

HIGHLIGHTS

The principal observations/findings of each chapter are summarized below to provide the reader with a capsule summary of the report. Pages where a more detailed discussion can be found are identified in parentheses following each item listed.

Land-Use Planning

- Comprehensive land-use planning is critical to the overall management of a city's resources because of land's unique nature as a basic physical resource and the role it plays in developing plans and strategies for all other sectors. (II-1)

- Countries and their respective cities can be classified in a general way according to their socioeconomic physical characteristics, and "stage" of development; the classification scheme is a useful way of identifying a city's "readiness" to adopt land-use strategies of varying degrees of sophistication. (II-1 thru II-3)

- Land-use planning tools can be conveniently classified at three levels of analysis and application: (1) techniques generally involving some form of direct government intervention (e.g., zoning ordinances, building codes), (2) specific standards and/or areas of application (e.g., building and street orientation), and (3) information and analysis methods used to develop specific standards and apply available techniques. (II-3 thru II-16)

- Major constraints to the successful application of land-use planning tools include: lack of overall policies and goals, lack of information, and lack of managerial skills and trained resource people. The rigidity of land-use planning techniques (e.g., the time and cost of preparing and modifying plans and ordinances) also is a constraining condition as are the rapid rate of population growth and extensive land speculation occurring in developing countries. (II-4 thru II-5)

- Provision of infrastructure (e.g., streets and roads, water and sewer) is considered "... the single most powerful land-use shaping technique at government's disposal, short of actual land acquisition and building construction" (Rivkin [5]). More generally, the land-use development planning process must be linked to a city's capital improvements and operating budgets in order to effect appropriate coordination between the timing of projects and their financing. (II-6 thru II-9)

- Codes and ordinances that are basic to city management include zoning, subdivision controls and building codes; they must be adapted to each local situation, and an effective permit/enforcement system must be established. (II-9 thru II-10)

- Specific standards to achieve energy and resource conservation include: (1) site design and microclimate (e.g., building orientation to the South); (2) housing density, land-use integration, transportation; and (3) implementation techniques as described above. There is a general movement toward mixed-use projects, projects of a neighborhood scale, high-density employment centers, and use of infill techniques. (II-11 thru II-14)

- Several sources provide lists of information requirements (e.g., resources and activities to be analyzed) and analytical points to consider in assessing a city's "situation" as part of the plan development process. (II-14 thru II-16)

- Several case studies are available, but the most detailed attempts at "Energy-efficient Land-use Planning" were found in the United States. In terms of scale and appropriateness of technologies and management systems used, the experience of such communities as those participating in the U.S. Department of Energy's Site and Neighborhood Design (SAND) program, such cities as Davis, California, and such states as Oregon may be transferrable to a degree to developing countries and their respective cities. (II-17 thru II-19)

Transportation

- The automobile fleet in Third-World countries is expected to quintuple between 1975 and 2000 at the same time that population in urban areas of South Asia is expected to more than double. This presents smaller, growing cities with both a problem (to deal with the anticipated growth) and an opportunity (to learn from the experiences of larger cities). (III-1 thru III-2)

- Although traffic congestion is a major problem, attempts to discourage use of private automobiles have not been successful; a high correlation exists between increasing income levels and increasing car ownership, and the low quality of bus service has made the marginal cost of driving much lower than taking the bus. Commercial traffic (e.g., trucks, carts) compounds the problem because of the absence of central terminal facilities ad warehouses. (III-2 thru III-6)

- Transport investments generally consume 20% to 25% of total urban budgets, a large portion of which is directed to street maintenance. In addition, transportation is generally the responsibility of several agencies at different levels of government that are generally autonomous. Enforcement of traffic regulations is almost always a problem because of understaffed police and the piecemeal way in which traffic codes are developed. (III-6 thru III-7)

- The general principles of resource conservation and reduction of travel time discussed in the literature are as follows: (1) reduce traffic congestion through traffic management (e.g., access system, reduction of conflicts, increased vehicle occupancy), (2) shift from private to public transport, (3) develop labor-intensive construction and maintenance programs to provide employment and simultaneously conserve capital and fuel, and (4) improve "urban form" (as described under the land-use planning section). (III-8 thru III-25)

- The majority of case studies in developing countries apply to large cities, e.g., Singapore, Bangkok, Curitiba (Brazil); limited experiments involving road systems, bikeways and pedestrian crossings, special bus facilities, and parking controls are reported in twelve cities. (III-30 thru III-35)

Energy and Electric Power Systems

- Developing countries have been conveniently grouped according to whether they are "oil importing developing countries" (OIDCs) or merely less-developed countries with substantial oil (and related) energy reserves (LDCs). For OIDCs (e.g., the Philippines), a stress has been placed on developing such non-conventional energy resources as biomass (combustible and/or fermentable material of an organic nature), wind, geothermal (superheated water and steam contained in underground aquifers), and small hydro. (IV-1)

- Inefficient and unreliable electric power, transmission and distribution systems are common to all developing countries. The old and poorly maintained electrically-driven equipment generally used in LDCs compounds the problem by draining the electricity that reaches the end-users. Greater stress will be placed on these systems, regardless of the fuel used in generation, because of rapid growth expected in energy consumption from 1980-1990 in LDCs (6.2% per year). (II-1 thru II-2)

- The use of traditional fuels offers an efficient way to satisfy the growing demands of the household sector in LDCs (e.g., for cooking, water heating and space heating). Conservation within the industrial sector offers considerable potential because of the intensive use of energy by primary industries and the present inefficiencies of existing machinery. While the transportation sector is also a major energy consumer (petroleum-based products), conservation may be difficult for reasons discussed in Chapter III. (IV-12 thru IV-15)

- With respect to electric power supply, growth in demand during the 1980s is expected to exceed 8% per year, and the overall use of electricity is expected to reach 31% of total commercial (purchased) consumption by LDCs in 1990, a substantial increase from its present level of 25 percent. Oil is expected to diminish as a generating fuel, with natural gas, coal, nuclear, and geothermal increasing in importance. Significant variations exist in capital outlays and operating costs of generating facilities depending upon capacity and type of fuel(s) burned. (IV-16 thru IV-17)

- In LDCs, energy losses exist throughout the generations, transmission and distribution systems

  .. 72% average heat loss at generation
  .. 10%-25% loss (of remaining amount) in transmission and distribution
  .. additional losses by end-users through lack of efficient equipment.

  Thus, there is significant opportunity for conservation strategies to be developed by utilities (use of grids to capture scale economies, use of efficient switching equipment, effective load management, appropriate pricing policies) and industrial power users (e.g., productive use of waste heat, efficient plant illumination and ventilation, purchase and proper maintenance of energy-efficient equipment). (IV-16 thru IV-23)

- An effective conservation program must be accompanied by technical assistance, data collection and monitoring, and public education programs (e.g., in encouraging households to convert to energy-efficient stoves utilizing wood, charcoal, and/or low-grade fuels). (IV-25 thru IV-27)

Water and Sewer

- Water and sewer problems include: poor delivery systems; inadequate and scarce water resources; contamination of water by sewerage and waste; lack of capital; lack of efficient operation and maintenance; transmission and distribution system losses; and lack of training personnel. (IV-1 thru IV-4)

- The location of water and impact on the human environment are contributing factors to a community's growth. Settlements may cluster near supply points and stimulate growth and further demand for water. Similarly, if water and sewer programs are appropriately directed, the human environment benefits greatly. (IV-4 thru IV-5)

- The literature reviewed identifies numerous low-cost, appropriate technological options for sewer/sanitation. Climatic, socioeconomic and problematic considerations are essential in implementing such approaches. (IV-5 thru 7, 12 thru 20).

- Water resource management and conservation issues require attention to prevent flooding damage, the spread of disease, and the retention and maintenance of water, especially in water scarce areas. (IV-7 thru IV-9)

- The development of institutional and managerial systems is essential for any strategy and water and sewer program. This system includes financial and human resources; coordination with other government entities and the community; government commitment; appropriate lines of communication; technical assistance; and potential for personnel development. Important also are the sensitivites of the social and cultural factors of the country and community and the involvement of the target population in the project. (IV-9 thru 11, 23 thru 24)

- Water and sewer rates are important to a municipality or local utility. Several factors affect the cost of water and sewer services including: (1) geography; (2) demand; (3) customer constituency; (4) level of subsidization; (5) age of the system; and (6) the rate methodology. (IV-20 thru 23)

Solid Waste Management

- Inadequate and inequitable collection and disposal of solid waste (refuse) create severe environmental and health hazards. Common to many LDC cities is the problem of fecal material mixed in with municipal

refuse. Both industrial and decomposed organic waste can seep into already overloaded water and sanitation systems via groundwater, drainage canals, and sewage pipes. However, the upgrading of solid waste management has received little attention as a potential source of energy and resource savings. (IV-1 thru IV-4)

- The categories of municipal waste generally include: (1) household garbage and rubbish, (2) commercial refuse, (3) institutional refuse, (4) street sweeping, (5) construction and demolition debris, (6) sanitation residuals, and (7) industrial wastes. Their characteristics and subsequent disposal methods vary significantly. The differences are often attributed to cultural factors. A comprehensive survey of waste characteristics and collection practices is a major element to planning for improved quality of service. (IV-4 thru IV-9)

- Solid Waste Management is concerned primarily with four functions: collection, transport, processing and diposal. Reducing the use of mechanical systems to carry out these functions can provide more energy-efficient and equitable service. A number of ways exist to improve the adequacy of service. Sanitary landfills can provide attractive disposal sites that reduce the problems associated with disposal. Important to the planning effort are the social and cultural aspects of refuse. (IV-10 thru IV-16)

- Updating of long-term planning and implementation strategies is an ongoing process that emphasizes information dissemination, full community participation and interaction of municipal departments. Short-term steps might include: (1) optimize collection routes, (2) upgrade existing disposal sites and locate new ones, (3) discontinue open dumping as soon as feasible, (4) review the rate structure, accounting and billing procedures, (5) use sufficient vehicles to provide adequate service (including human and animal drawn), and (6) encourage resource recovery by organizing scavengers and provide them with equipment and a safe working environment. (IV-17 thru IV-21)

Building Design and Materials

- Energy devoted to the heating, cooling and lighting of both residential and commercial structures consumes nearly 10% of the Third World's annual energy supplies. Moreover, approximately two-thirds of this

energy is derived directly or indirectly from petroleum and natural gas. Other energy expenditures, such as the manufacture, transportation and importation of building materials -- which are frequently inefficient processes -- create a further drain on scarce resources. (VII-I)

- There are two primary contributing factors aggravating the architecture and energy situation in LDC urban areas: (1) high rates of population growth and rapid in-migration to urban centers that place intensive pressure on the demand for existing and new shelter; (2) discontinued use of traditional climate-conscious architectural styles and indigenous building materials with "modern" western influenced designs that rely heavily on energy-intensive, mechanical climate control. (VII-1 thru VII-2)

- Planning tools for energy and resource efficiency in the building sector stress adherence to five interrelated tasks: (1) conduct building climatology research -- use indigenous resources, (2) develop intermediate technologies and building systems, (3) involve community-wide participation in conservation projects, (4) use energy-efficient building designs and materials, (5) plan building renovation projects in conjunction with new construction. (VII-3 thru VII-4)

- The benefit of climate-conscious design is that it conserves valuable energy and natural resources while improving health and housing conditions. Specific approaches consider: (1) site selection and orientation, (2) absorption, insulation, heating storage, (3) shading, solar radiation control, (4) roof design, (5) ventilation, and (6) air cooling. (VII-6 thru VII-11)

- Several sources provide information on building with indigenous and renewable materials and methods. None, though, adequately evaluates the energy and resource performance in either theoretical or empirical terms. The usage of particular materials is discussed on pages VII-11 and VII-12, and additional comments are interspersed throughout the text.

- The case studies available detail attempts or proposed architectural applications using principles of climate-conscious design. One example is the Government Service Insurance Systems (GSIS) building in Manila, Philippines, which will realize a 50% energy use reduction over a comparable sized building. Natural lighting, induced ventilation, and orientation for daylight will significantly decrease the use of the auxiliary air conditioning and artificial lighting systems. (VII-12 thru VII-18)

II. LAND-USE PLANNING

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INTRODUCTION

This chapter of the state-of-the-art report (SOTA)/field guide addresses the relationship between land-use patterns and resource conservation. More specifically, it deals with land use in intermediate-sized cities and the role of city government in effecting a more efficient resource utilization pattern.

Because land is a basic physical resource upon which cities are built, there is a natural interaction between land-use planning and all other topics or sectors covered in this SOTA review/field guide. For example, a transportation system is developed based upon land configuration; centers of residential, business, recreational and other activities; such natural barriers as rivers, hillsides, flatlands; and so forth. Similar interrelationships exist between land-use patterns/planning and electric power systems (e.g., layout of distribution lines), water and sewer systems, solid waste and resource recovery systems (e.g., location of collection, disposal, and recycling centers), and the use of building materials and establishment of building standards (e.g., height limitations, resource efficient design and configuration).

Beier, et al. [2] identify several problems faced by cities in less-developed countries (LDC's) as they attempt to absorb over 1 billion people between 1975 and the year 2000. According to Beier, et al., "the core of a programme to improve the absorptive capacity of cities will be a programme to increase their efficiency."[1] Beier, et al. identify several inefficiencies in cities that serve as constraints in their ability to absorb growth and provide job opportunities and reasonable incomes to their residents, e.g., provision of services and utilization of labor.

To assist in understanding the current status of existing countries, Beier, et al. have developed a typology which provides

a means for classifying countries and their respective cities for analytical purposes:

- Type I: a large portion of the population already urban; small percentage of "very poor" people; problem of absorbing large numbers of rural poor into cities; primary problems are land speculation, widespread illegal squatting and truncated urban service infrastructure.

- Type II: more poverty and severity of problems than Type I countries; rural migration will continue to cities, particularly in countries like the Philippines where agricultural incomes continue to decline; the Philippines and Malaysia have industrial systems characterized by relatively high protection and restrictive labor markets, whereas Korea has developed a "self-sustaining, internationally competitive manufacturing sector and good urban-rural distribution of incomes;"[2] backlog of services calls for interim solutions below potential long-run standards (the Philippines has relatively severe problems).

- Type III: generally includes African countries which are at an earlier stage of development (smaller cities, spatial and economic character of countries in year 2000 difficult to predict); primarily rural economics for next 20 years; require major improvement in agricultural policies and systems with gradual transition to urbanization; tremendous pressures exerted by rural poor on resource base; resource base still a key (e.g., Zambia and Botswana with mineral wealth can affect movement to urban areas by providing water and sewer, education and other services in contrast to Kenya without this resource base); Malawi has been able to create new urban land, subdivided, lightly serviced, at low cost (appropriate scale); need to get labor market in balance with appropriate pay scale for civil servants relative to other markets and reduced use of licensing, standards and administrative procedures to restrict market entry.

- Type IV: primarily rural economies with 20% of population in cities; require rapid agricultural development; cities face long-run absorption problem; lagging service provision leading to major squatter problem; lack of water, sewer, road systems, waste removal, drainage (e.g., India, Pakistan); inability to finance, administer any large-scale human settlements' program.

Although no typology can be "clean" in terms of cut-off points between classes or types of countries and their respective cities, the above categorization provides a reasonable basis for distinguishing among areas based on their stage of development and resource/developmental constraints. The types of tools countries use in their land-use planning strategies, and the way in which they are applied, will vary on the basis of city "type" and specific areas of opportunity identified.

LAND-USE PLANNING TOOLS

The literature addressing land-use planning and resource efficiency provides valuable information on three levels of analysis and application:

(1) Techniques usually involving some direct intervention by local government, e.g., provision of infrastructure in selected areas; controlling the nature of development through codes and ordinances; use of more advanced capital budgeting and impact planning techniques to allocate resources.

(2) Specific standards and/or areas of application of planning techniques, e.g., building and street orientation, use of vegetation and landscaping, integration of land uses.

(3) Information to analyze in applying standards and developing specific rules and regulations, e.g., existing resources and activities, nature of development centers, existing spatial linkages within the greater region.

Rivkin [6] provides the most lucid discussion of the factors affecting land use, the rationale for government intervention,

and the constraints to effective land-use planning.[3] Factors affecting the existing use of land include topography and soils, tenure arrangements, existing patterns of use and ownership, and the nature of prices. Rivkin suggests that government intervention is only one part of the land-use process and that the price mechanism, which serves to allocate available land among competing uses and densities, must be clearly understood by local officials in the development and application of land-use tools.[4]

The rationale for government intervention in the land-use market is based upon the belief that the private marketplace cannot produce a rationale, efficient land-use system that treats people equitably and accounts for the needs of future generations. Essentially, the price mechanism does not adequately take into account such factors as provision of infrastructure and support facilities (e.g., education systems and police and fire protection) and such "spillover" effects as congestion, crime and public health hazards. Rivkin suggests a "schema of objectives"[5] including efficiency (balancing demands and services); health, safety and welfare (construction standards, limit of pollutant emissions, limit overcrowding), equity (access to all groups, protection of ownership rights), adaptability (including expansion and conservation), and conflict resolution.

Constraints to regulation and control include the following factors:[6]

- Lack of priority and policy: Limited attention paid to rationalizing land-use planning; attempt to establish physical form and design without regard to efficiency, equity, adaptability, e.g., adapting models of developed countries that are unsuitable for LDC's and are, hence, unenforceable and may produce undesired results.

- Lack of information: records of existing land-use patterns, ownership, density, physical characteristics and socioeconomic information are required as a minimum (see discussion of information checklists below) to develop sound planning systems; the data base is generally inadequate.

- Lack of manpower and managerial skills: unavailability of trained professionals to develop plans and formulate regulations; frequently subject to graft and corruption because of impact on land uses and values.

- Excessive speculation: principal focus of investment in developing countries and difficulty in separating speculators from class of people in control of government.

- Rate of growth: often so rapid (due to population immigration and natural rate of increase) that rule-setting cannot be devised, updated, and enforced adequately.

- Rigidity of techniques: inability to change master plans, rules, ordinances in response to changing technologies, patterns of growth, and so forth.

Intervention Techniques

Specific techniques utilized in land-use planning are discussed by Rivkin [6], Harwood [4] and the American Planning Association (APA-[1]). While Rivkin addresses land-use planning in developing countries and both Harwood and the APA address "energy-efficient" land use in the United States, the techniques discussed are quite similar (although their application would not necessarily be), with Rivkin again providing the most comprehensive classification scheme:[7]

- Government as actor in the development process:

  .. infrastructure provision
  .. land acquisition
  .. government as developer/financier
  .. public/private interaction
  .. slum or squatter removal

- Government establishes and enforces "rules of the game":

  .. planning
  .. codes and ordinances: zoning, subdivision, building, traffic
  .. withholding of permission
  .. value freezing
  .. taxation

- Combination of rulesetting and direct public investment to channel short-term decision-making on land use (presently being tested in developing countries):

  .. infrastructure impact planning
  .. guidelines for planning critical areas
  .. capital budgeting

The APA discusses several of the above techniques in a section entitled "Implementation."[8] This section contains a combination of specific area studies in the United States (e.g., Davis, California; Salem, Oregon) and a review of techniques utilized under land-use regulation, zoning ordinances, and subdivision regulations, but with a stress on energy and resource conservation.

Government As Actor

The areas included under Rivkin's first category, "government as actor," are generally straightforward. Infrastructive provision is described as "...the single most powerful land-use shaping technique at government's disposal, short of actual land acquisition and building construction."[9] A weakness in this area has been its responsiveness to problems as they arise rather than its use to direct development and plan for the future in a coordinated manner. In larger cities, a problem has been the displacement of residential units by high-rise commercial buildings, forcing residential units to be reconstructed in areas without adequate physical infrastructure or support facilities (e.g., schools, recreation, medical facilities). The ability to provide new facilities and/or rebuild old facilities is integrally linked to the strength of a city's economy and its ability to use innovative financing techniques (discussed under "rules of the game").

Direct land acquisition may be required in support of facility provision (e.g., a site for a school; space for road widening). Again, a problem faced by developing countries is responding to problems as opposed to planning in advance, leading to bottlenecks and costly solutions. Some specific types of acquisition discussed by Rivkin are as follows:

- Acquisition for specific facilities: This can be accomplised by government using its powers of eminent domain to acquire land for public services.

- Excess acquisition for earmarked facilities or general development purposes. This technique allows government to expand acquisition to include surrounding lands to an area acquired for a specific purpose. In this way government can effectively control development activities which are attracted by the existence of infrastructure. Little evidence of the degree to which it has been employed in LDC's is available.

- Land banking: This technique consists of the acquisition of land by the government well in advance of need. This is determined by the prospects of growth of a city and the perceived need that government has for providing infrastructure and services in the future. The creation of land development authorities has been proposed for this purpose. Cities desiring to implement such programs require considerable financial and management support in addition to careful advance planning.

Government has most often played the role of developer in the case of providing low-income housing, where subsidies are required. In developing countries, the role has most frequently been played by the central government because of financial contraints felt by individual cities. Malaysia's Urban Development Authority is an example of a national government participating actively in comprehensive development (commercial projects, shopping centers), but its activities have not been evaluated (as of 1979). Again, financial and management constraints exist to implement this type of program successfully, particularly at the local level. Public/private participation is similar to the Malaysian example except that government generally acquires, replats and improves land and then either resells it to private interests for development purposes or participates on a joint-venture basis with private developers.

The final area where government is a direct actor is in squatter removal. This often requires a resettlement scheme and

preparation of the sites for new uses. A local government encounters difficulty with implementation of this type of program when adequate housing substitutes cannot be provided; squatter settlements continually reappear in new places, and the process is recreated. Relocation also requires human sensitivity which is difficult to apply, particularly when financial and managerial resources are not available.

Government Enforcement of "Rules of The Game"

The first area covered by Rivkin under this category is planning itself, wherein government defines a framework for land-use decision-making. An important element of effective land-use planning is a balance between guidelines and implementation ability and the avoidance of rigid standards. The majority of plans cited by Rivkin are national in scope (Singapore, Malaysia, Brazil) and do not discuss the role of cities relative to national units of government, although Rivkin covers the Brazilian case in a previous study addressing land-use planning in intermediate-sized cities (see general bibliography). A general series of steps recommended is as follows:[10]

- Preparation of goals and objectives for land use and facilities.
- Preparation of population forecasts and forecasts of economic trends as they relate to physical needs.
- Preparation of generalized land-use and transportation guides.
- Preparation of furctional plans and programs which identify (potential) sites and capacities of schools, health facilities, roads, utilities, etc. (relative to projected needs)
- Definition of timing, staging and linkages.
- Implementation program involving legislation, government, private action.

The area of critical importance is the linkage of the plan to the capital investment and credit policies of the government, and the

creation of administrative machinery to implement the plan and modify it as conditions warrant.

Codes and ordinances are basic to city management and include zoning subdivision controls and building codes, defined as follows:

- Zoning. This consists of the division of a particular area into an array of districts and the establishment of regulations governing each one of them according to their assigned use. There are several types of zoning, some of which are:

  - Mixed use development zoning
  - Transit impact zoning
  - Cluster zoning
  - Floating zoning
  - Planned unit development zoning
  - Conditional or contract zoning
  - Interim zoning

- Subdivision controls. These are instruments which regulate the actual development of a specific site. They include the standards for street improvement, lot sizes and layouts and guidelines for the dedication of private lands to public purposes.

- Building codes. These regulations assure the adequacy of structures in such matters as resistance to fire and natural disasters. They include such specific elements as materials, floor area loadings, plumbing, and sometimes room sizes and maximum occupancy levels.

The nature of these codes and ordinances is preventive and usually leads to a permitting system. Codes are generally either components of a master plan or are separate instruments enforced by a local building department. However, problems exist in adapting standards borrowed from one situation to the construction conditions and land-use patterns of a particular country or city. Often, standards too high (e.g., housing standards) or unsuited (inappropriate street widths) to a situation result. However, some level of minimum platting requirements, service provision and construction regulations is required. Inadequate administration and corruption often result, particularly where

standards are "unreasonable" and incentives to circumvent them are strong.

The APA [1] addresses land-use regulations, zoning and subdivision regulations from the perspective of energy and resource conservation. General policies applicable to land-use include, among others, limitation of low-density "sprawl" and development of mixed-use projects to reduce transportation costs; "infilling" of vacant land and revitalization of older structures; and development of compact "satellite" communities while retaining the downtown area as a focal point of economic and government activity. Modification of zoning ordinances to encourage mixed-use projects, intensive development around transit stations, creation of "Planned-United Developments" (PUD's), changes in setback and yard requirements (encouragement of clustering), and tree protection/vegetation shading will result in reduced construction costs (including utilities) and energy costs. In the area of subdivision regulation, flexibility in street layout and design (reduced street length, bikeways) can lead to energy savings and improved solar access.

Final areas addressed by Rivkin in this area include "value-freezing" and taxation. Value-freezing is a form of control over use between eminent domain (the government doesn't actually acquire the land) and other forms of purchase that are intended to control the sale price and thus the ultimate use of the land. Taxation is discussed in the context of control over speculation by levying some type of site value tax or excess profits tax. It is also described as an incentive (i.e., reduction of tax burden) to encourage particular types of land utilization.

Combined Rulesetting and Direct Public Investment

This final area under intervention techniques is described by Rivkin as "some promising new approaches."[11] In this context, techniques are considered as necessary but not sufficient for effective land-use planning. More important are quality personnel, commitment level to incorporate land-use concerns into basic

development policies, and financial resources that can be devoted to investment and administrative measures on a priority basis. The three areas covered -- infrastructure impact planning, guidelines planning for critical areas, and capital budgeting -- are targeted approaches to development only recently being employed in developing countries. A more complex technique, such as transferring of development rights, requiring modeling based on extensive information and complicated monitoring arrangements, is not suggested by Rivkin for developing countries. The three areas can be described briefly as follows:

- Infrastructure Impact Planning. This is an analytical exercise which consists of the assessment and organization of secondary impacts that might arise from the undertaking of major infrastructure investments. These techniques allow for taking into account the implications that such undertakings may have on land-use patterns. Traditional approaches can be utilized in conjunction with an impact assessment (e.g., site assembly in anticipation of future development).

- Guideline planning for critical areas. Involves selective approach to planning in such areas as coastal regions and environmentally sensitive watersheds where resource conservation is generally of great concern.

- Capital budget. Development of a budget of planned capital outlays over a period of years (five or more) so that major infrastructure investments can be programmed in accordance with development needs and available financial and human resources. It also identifies areas of complementarity (e.g., industrial growth requires utilities up-front followed by public services) and areas of impact not necessarily anticipated. An example cited by Rivkin is the Karachi (Pakistan) master plan.

Specific Standards to Achieve Energy and Resource Conservation

This classification within "Land-Use Planning Tools" is designed to go one step beyond the techniques discussed above to provide a sampling of specific types of standards used to achieve energy and resource conservation. The principal source of these approaches is the APA [1] which is itself a state-of-the-art

(SOTA) review applicable to the United States experience. Other references describing case study applications are Ridgeway [5] and the Urban Land Institute [8], again providing applications within the United States. Only Rivkin, cited previously, provides general applications to developing countries (Turkey, Brazil, Malaysia), but without special emphasis to energy and resource conservation.

The APA organizes its discussion of energy-efficient land-use techniques as follows:

- Site design and microclimate

  .. Site selection and topography
  .. building and street orientation
  .. vegetation and landscaping

- Housing density, land-use integration, transportation

  .. Housing type and density
  .. integration of land uses
  .. transportation and circulation systems
  .. promoting the use of mass transportation (for larger cities)

- Implementation (discussed above)

  .. background studies
  .. policies, plans, legislation
  .. land-use regulations
  .. zoning ordinances
  .. subdivision regulations

Some of the same concerns are raised in the APA study as described by Rivkin, e.g., the relationship of efficient land-use planning to public service costs, housing costs, preservation of prime farmland, and overall fiscal balance. The areas discussed by the APA are intended for use primarily on a project-by-project basis, but can also be applied to comprehensive planning.

Within the first area of site design and microclimate, site selection and topography are discussed in the context of such relatively technical aspects as elevation, angle, direction of

slope and the effect of the sun, wind velocity and coolness of air through use of prevailing winds. An area of particular significance is the dependence of design on climate zone (e.g., cool, temperate, hot-arid, hot-humid). In the case of hot-humid (tropical), access to breezes is critical. Ideal siting possibilities include development on slopes (near hillcrests), with maximum south (and north) exposure to limit impact of solar radiation with shading techniques (trees) used where possible. West-facing surfaces overheat the most and location close to water can provide natural cooling. Other factors to consider include land availability and cost and erosion hazards in hilly areas.

Buildings and streets should be designed for maximum south orientation of structures (in terms of window area) to achieve maximum solar efficiency, and, in hot regions, access to breezes is important. This suggests a main network of streets going east-west where possible. Trees and shelter belts can be utilized to shade houses and to both shade and protect pedestrians and bikers (e.g., exterior shading with trees is up to seven times more effective than interior shading).

Within the second area of site design, approaches to energy and resource efficient housing density/configuration include clustering (reducing street length and utility installation cost), common-wall construction (reduced cost and outside exposure; dual insulation) and increased density in addition to the above approaches through smaller-sized structures. The literature suggests medium-density and low rise/multi-unit structures as being most energy efficient; high rise buildings have extensive utility hook-ups (vertically) and high elevator installation/operating costs.

Integration of land uses was discussed in the previous section and includes the following examples:

- Movement toward multi-purpose land and facility use (mixed-use)

- Projects of neighborhood scale: integrated convenience stores, low-density office, schools, recreation, activity centers

- High-density employment center surrounded by low- or moderate-density residential and/or low degree of overall centralization through neighborhood clustering

- Use of infill techniques: utilize skipped-over parcels through incorporation into redevelopment plans, incentives, relaxation of zoning provisions.

Related to integrated land-use are improved transportation/circulation systems, designed as a uniform network of streets, sidewalks, footpaths, bike paths, and public transit connection points. Efficient street design is a specific application of the approach to reduce excessive widths of traditional grid layouts and to improve materials usage and design to reduce summer temperatures of roads. Care has to be taken to plan for necessary access by emergency vehicles and pedestrian safety.

General Information Requirements

Moving to even greater specificity are studies that provide listing and/or assessments of information requirements to apply intervention techniques and/or specific approaches to energy and resource conservation. Principal studies covering this area, in addition to limited material covered in those cited above, include those of Boyden [3], Rondinelli and Ruddle [7], and the World Bank [9]. Boyden deals with an "integrated ecological approach" (to the study of human settlements); Rondinelli and Ruddle are concerned with a "spatial policy for equitable growth;" the World Bank is concerned with renewable energy resources in general, providing interaction with the land-use principles discussed in this chapter.

Although Boyden is working as part of the United Nations Educational, Scientific and Cultural Organization (UNESCO) Series on Man and the Biosphere (MAB), he does present a series of

points in addressing land use and natural resources interaction that is of interest to land-use planning:[12]

- "Where there is variability in soil fertility in a region, it is preferable for the built-environment to be constructed on least fertile soil, leaving more fertile soils for primary (agricultural) production
- "Excessive and unnecessary clearing of natural vegetation as a concomitant to agricultural or mining operations may contribute to loss of diversity among animal and plant species, erosion, and general deterioration in soil quality and in the aesthetic qualities of the natural environment.
- "Possibilities exist in some countries for encouraging use of land within cities for primary production, especially horticulture; such developments have implications not only for the nutrient budget of the cities, but also for the quality of life of their inhabitants.
- "Farming practices and industrial activities may interfere with natural and essential biogeochemical cycles (e.g., phosphorous and nitrogen).
- "Multiple use of land is sometimes feasible; for example, areas of forest near cities may provide timber, protect against erosion, and act as an effective recreational area for city dwellers."

Boyden also presents a series of charts and diagrams in his conceptual approach to "integrative ecological studies." There are four checklists which provide helpful information in assessing land-use planning and development approaches from an environmental/ecological perspective: (1) life conditions checklist, (2) biopsychic state checklist, (3) total environment checklist: components and processes, (4) total environment checklist: aspects. For example, the "life conditions" checklist includes material (e.g., air quality), behavioral (time budget in terms of such activities as physical work), social (e.g., population density), and general (e.g., variety of daily experience).

In their chapter entitled, "Urbanization and Rural Development: Transforming Spatial Structures in Developing Nations," Rondinelli and Ruddle discuss the connection between spatial

linkages and transformation (physical linkages, economic linkages, population movement linkages, technological linkages, social interaction linkages, service delivery linkages, and political-administrative-organizational linkages). In discussing the building of development centers and location of urban services and facilities, they include a table relating type of analysis, elements of analysis, alternative methodologies, and types of information. Three types of analysis are included: (1) analysis of rural resources and activities, (2) analysis of development centers, and (3) analysis of regional spatial linkages. The methodologies and analyses suggested can also play an integral role in effective land use and development planning (e.g., use of aerial photography and mapping to describe physical land characteristics and resource use) and serve as a useful guide to those undertaking the land-use planning process.

A final publication providing general information requirements is the World Bank's concise discussion of renewable energy resources in developing countries [9]. While the majority of issues and applications described in this publication are discussed under the topics Energy & Electric Power and Solid Waste & Resource Recovery, the book provides an overview of technologies suitable for developing countries that have direct implications for the preparation of land-use plans, building codes, and related tools. In addition to a very useful glossary of terms, the publication discusses the potential of renewable energy (conservation and increased efficiency in energy use are helpful but not sufficient to meet growing needs); specific renewable energy needs appropriate to rural areas and smaller cities (e.g., use of firewood, charcoal, crop residues/animal dung) and the rapid depletion of firewood sources; and appropriate technologies for consideration (variety of stoves and rural power technologies) in addition to the use of alcohol and biomass pyrolysis utilizing residuals as fuels and capturing by-products for reuse. African countries are most dependent on renewable resources for energy, Latin America the least. The World Bank is presently stressing fuelwood and alcohol production and the

building of local capacity to develop operational experience and management capacity.

CASE STUDY DISCUSSIONS AND IMPLEMENTATION ISSUES

Other than Rivkin's discussion of the application of land-use techniques in three developing countries [6], the majority of case study materials reviewed utilize a United States context in treating the specific issue of resource and energy efficiency. Ridgeway [5] and the Urban Land Institute (ULI [8]) provide several case study discussions that illustrate the use of one or more specific techniques. The APA (1) publication utilized in the previous section discusses specific applications within the context of implementation, providing a logical conclusion to the SOTA.

The communities discussed by Ridgeway and general land-use practices covered are as follows:

- Hartford, Connecticut: stress on urban agriculture to reduce food production and distribution costs, while employing the City's poor.
- Northglenn, Colorado: a small city utilizing an innovative water and wastewater management system stressing the recycling of wastewater from households for agricultural and related uses.
- Seattle, Washington: use of housing and transportation planning designed to conserve energy through building codes and public transit; also encouraging urban agriculture and utilization of biomass from fast growing trees for power generation.
- Davis, California: adoption of a controlled growth plan over the past 10 years including stringent building codes, design of narrow, tree-lined streets, and public transit.

Other case studies of possible applicability to developing countries include Ames, Iowa (energy from waste), Clayton, New Mexico (windmill), and Burlington, Vermont (wood). The book concludes with a "checklist for energy action" and description of basic ingredients for an energy and resource conservation stra-

tegy (reorganize transportation system; direct housing to the center city away from additional suburban growth; capture, control and reuse waste materials).

On the basis of scale and direct applicability to intermediate-sized cities in developing countries, the Davis and Northglenn cases would appear most applicable. The Davis experience goes back over a decade, and the city has produced several documents (e.g., building code, general plan) applicable to other communities. The city's efforts also include a resource recycling program. Northglenn's program is directed more specifically to recycling scarce water from storm and sanitary sewers for agricultural uses. The program would have limited applicability to a developing city without a sanitary sewer system and would have to focus on stormwater recovery unless technologies to deal with waste materials in small neighborhoods are available and economical to use.

The ULI report deals with energy efficient community development techniques (community generally under 50,000 people and study areas generally under 1,000 acres) under an experimental U.S. Department of Energy program (Site and Neighborhood Design -- SAND). Most communities are of the planned unit development (PUD) type and very affluent by LDC standards. Examples include:

- Burke Center, Virginia: 15,000 people, mixed residential/commercial, using extensive land/site planning techniques, transportation systems, and solid waste collection.

- Greenbrier, Virginia: 14,000 people, 719 acre study area for single-family use employing siting, infrastructure and groundwater heat pumps for energy conservation.

- Radisson, New York: 140-acre study area including town commercial center and mixed residential developments; focus on passive siting to reduce high winter energy demand.

- Shenandoah, Georgia: 255-acre residential study area to use large-scale site design and solar technology in humid subtropical climate.

- The Woodlands, Texas: 500-acre SAND study area including major regional center for mixed commercial, office and light industrial uses.

A checklist of energy-efficient techniques used by each project is provided (land/site planning, architectural, mechanical, consumer/community systems and operations). Possible impediments to implementation are identified as marketability (uncertainty of exact energy savings; lack of performance guarantee to owners), role of leadership (public sector role and competitiveness), cost/benefit accrual (developer bearing entire risk), development regulations (possible deterrents), technical know-how. A list of communities with energy-efficient development regulations is also provided, classified by area of concentration (reducing heating and cooling needs; reducing transportation needs; reducing embodied energy; using alternative energy sources and systems). Davis, California, is the only city listed under each category.

Finally, the APA study cited above provides an implementation section describing the activities of such cities as Portland, Oregon (detailed energy use study), Davis, California (detailed analysis and implementation through building codes, zoning ordinance), and the state of Oregon through its Land Conservation and Development Commission (LCDC). The study lists detailed building and site standards, land-use planning guidelines, and economic development policies for several locations. The study concludes with an annotated bibliography on community energy audits.

LIST OF FOOTNOTES

1. Beier, *et al*, p. 397
2. *Ibid*., p. 402
3. Rivkin, pp. 87-93
4. *Ibid*., pp. 87
5. *Ibid*., pp. 89-90
6. *Ibid*., pp. 91-93
7. *Ibid*., pp. 103-104
8. APA, pp. 13-20
9. Rivkin, *op. cit*., p. 104
10. *Ibid*., p. 115
11. *Ibid*., p. 119
12. Boyden, p. 39

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III. TRANSPORTATION*

* This section of the report was prepared by David Whitman of Systan, Inc., Los Altos, California, under a consulting agreement with Coopers & Lybrand. It has been reviewed and edited by Coopers & Lybrand staff.

III. TRANSPORTATION

INTRODUCTION: MAJOR ISSUE AREAS

Achieving efficient urban transport has come to be viewed as an extremely pressing problem for the developing countries. Its condition in the larger cities is already critical, despite a currently low automobile ownership level, with severe congestion during extended periods of the day. Public transport is inadequate, requiring long waits for service on overcrowded vehicles, and even this service is priced out of the reach of a large portion of the urban poor.

The United Nations estimates that the urban population of the developing world will more than double by the turn of the century, growing in South Asia from 300 million to over 800 million.[1] The outlook for the growth of the automobile fleet is even more alarming. According to Organization for Economic Cooperation and Development (OECD) projections, the automobile fleet in the Third World countries will almost quintuple between 1975 and 2000.[2] Because automobiles in developing countries are heavily concentrated in the largest of the urban centers, the impact of these trends is most heavily felt there; accordingly the focus of most urban transport work by such funding organizations as the World Bank is on the principal cities. In South Asia these include Bangkok, Bombay, Calcutta, Jakarta, Kuala Lumpur, Manila, and Singapore.

For smaller cities, especially those under 500,000 in population, urban transport may be considered more as an opportunity than as a problem. Not only is street capacity still quite adequate in such cities, but lessons can be learned from the problems of the large metropolitan areas, and steps taken early to avoid the conditions which have led to their congestion. This is partly so because much can be done in terms of physical infrastructure (the provision of transport supply) to prepare for the coming of motorized transport since the smaller city is not heavily constrained by existing structures. Mostly, however, a

smaller city has the opportunity to plan the larger city it will be -- and to use the provision of transport to direct the growth in the desired locations.

Few studies have been conducted on the transport problems of small cities of the developing countries.[3] Therefore this report concentrates on the experiences of the larger cities and the conclusions which may be drawn for the smaller.

Congestion

In virtually all the largest cities of the developing world, congestion is generally described as appalling (2,3,4,6). Traffic moves at average speeds of 10 to 15 kilometers-per-hour (kph) over long periods of the day so that "peak" traffic hours are no longer recognizable. The main causes of this congestion are:

- Lack of Road Space. The total area devoted to streets is typically in the order of 10-15% (6), as opposed to the 15-30% range for cities in the developed countries. Many of the streets are less than 4 meters wide, barely able to permit two automobiles to pass. Furthermore, these streets are winding and intersect in complex manners, having "grown" before the days of vehicular traffic. This and the frequent changes in street width both contribute to the reduction of transport capacity.

- Intense Competition for Road Space. Because these cities are overcrowded, there is tremendous competition for the available road space by a wide variety of vehicles; bicycles, bullock carts, automobiles, trucks, motorized tricycles, barrows, donkeys, buses, and pedestrians all attempt to share the same space, with the average speed tending to be reduced to the slowest. In addition, the streets and sidewalks are often used for the non-traffic purposes of parking and trading, further reducing the available space.

- Location of Activity Centers. For historical reasons, the physical patterns of many cities contribute to congestion. Business centers have grown up around ports, and the combination of water and hills has forced elongated narrow urban forms, with residential areas far from the work centers.

This congestion has little apparent correlation to the level of automobile ownership -- both the richer and poorer cities suffer. In part, this is because the wealthier cities have already taken steps to increase road capacity by widening streets, often at the expense of sidewalks. This also is a function of the large number of trips which are abandoned or shifted to a different and less convenient time of day. Evidence exists that urban tripmakers exhibit a tendency toward a constancy of daily travel-time. Zahavi [7] terms this the travel-time "budget" and shows that this is stable over long periods (in the range of 1.25 hours in the U.S.). Therefore, reductions in average trip speeds reflect themselves in the abandonment of trips of lesser importance.

A consequence of this for the most congested cities is that even if major investments were to be made in the provision of road space, this would not significantly reduce the congestion because of the latent, suppressed demand.

Private Automobiles

The automobile is generally seen as the primary contributor to traffic congestion. Exhibit III-1 indicates that the capacity for passengers per unit width of street is approximately 10 times as great for a full-size bus with 30 passengers as for a one passenger car, despite the greater size of the vehicle, and most bus services in the developing cities carry far more than 30 passengers during the peak periods.[4] Furthermore, the private automobile is parked during the majority of the day, generally on the street. Owen [3] reports that a taxi utilizes one-sixth the road space per passenger than the private automobile. It seems conservative to estimate that unless off-street parking is available, an automobile increases congestion per passenger at a rate 20 to 30 times that of the bus. Therefore, even in cities with a currently low motor vehicle population (motorization level), the contribution by the personal car is already considerable.

Despite this undesirability, attempts to discourage the use of private automobiles have not been successful. The contrast between the European and the American experience is illuminating. U.S. policy has favored the automobile with low taxes, subsidies to highway construction and neglect of public transit. Many opposite policies have been in effect in Europe. Nevertheless, there has been little difference in the use of vehicles among travellers of the same income brackets [3].

The reason for this lies principally in the perceived cost of using the car versus the fare to be paid on the bus. The capital costs are very high relative to the bus and are generally not seen as part of the marginal costs. For a typical 5 km trip the fuel costs of a small automobile would be $0.25. The alternative bus trip would cost $0.05. If the car owner can park on the street at no cost, the total annual variable cost of driving to work appears to be less than 1% of the cost of the vehicle itself. Against that must be measured the discomfort and waiting required to use the bus.

Ownership and use of the private automobile have proven to be highly correlated with income levels. As per capita income increases, it appears inevitable that the rate of automobile ownership will also rise. Although heavy taxation on vehicle imports and fuel have some effect on the motorization level, this appears to slow the tide only temporarily.

Public Transport

Because of the currently low motorization levels in most Asian and African cities, the percentage of motorized trips taken on public modes ranges from 40% to 90% (most typically around 70%). Yet the number of buses per 1,000 population averages around 1.0 in most South East Asian cities (down to 0.3 in Bombay and Calcutta). In contrast, Washington, D.C. has about 3 buses per 1,000 population despite a relatively low (32%) share of the ridership by public modes.

EXHIBIT III-1

Illustrative Costs of Urban Travel by Different Modes

	Speed (miles per hour)	Persons per foot width[1] per hour	Track capital costs[2] Per hour	Track capital costs[2] Per person	Track maintenance costs[3] Per vehicle	Track maintenance costs[3] Per person	Vehicle operating costs[4] Per vehicle	Vehicle operating costs[4] Per person	Total costs per person US cents per mile
			US cents per mile		US cents per mile		US cents per mile		
Footway, 4 feet wide	2.1	1,100[5]	2	0	0	0	0	0	negligible
Bicycle track, 4 feet wide	8	450	50	0	0.3	0.3	0	0	0.3
Urban street, 24 feet wide, mixed traffic									
Car with driver only	15[6]	29	120	4.1	0.4	0.4	13.0	13.0	17.5
	10	51	120	2.4	0.4	0.4	14.6	14.6	17.4
Taxi with 4 passengers	12	120	120	1.0	0.4	0.1	13.6	3.4	4.5
	8.6	200	120	0.6	0.4	0.1	15.4	3.8	4.5
Minibus with 10 passengers	10	150	120	0.8	0.6	0.1	20.0	2.0	2.9
	7.5	250	120	0.5	0.6	0.1	24.0	2.4	3.0
Bus with 30 passengers	8.6	300	120	0.4	1.0	0	50.0	1.7	2.1
	6.7	500	120	0.2	1.0	0	60.0	2.0	2.2
Urban street, 44 feet wide, mixed traffic									
Car with driver only	15[6]	39	120	3.1	0.4	0.4	13.0	13.0	16.5
	10	55	120	2.2	0.4	0.4	14.6	14.6	17.2
Taxi with 4 passengers	12	160	120	0.8	0.4	0.1	13.6	3.4	4.3
	8.6	220	120	0.5	0.4	0.1	15.4	3.8	4.4
Minibus with 10 passengers	10	190	120	0.6	0.6	0.1	20.0	2.0	2.7
	7.5	280	120	0.4	0.6	0.1	24.0	2.4	2.9
Bus with 30 passengers	8.6	410	120	0.3	1.0	0	50.0	1.7	2.0
	6.7	550	120	0.2	1.0	0	60.0	2.0	2.2
Urban expressway (capacity per foot-width is independent of width)									
Car with driver only	40	180	900	5.0	0.4	0.4	11.0	11.0	16.4
Taxi with 4 passengers	40	720	900	1.2	0.4	0.1	11.2	2.8	4.1
Minibus with 10 passengers	40	1,200	900	0.8	0.6	0.1	17.0	1.7	2.6
Bus with 40 passengers	40	2,000[7]	900	0.4	1.0	0	43.0	1.1	1.5
Metro (22,500 passengers per hour)	21	1,700[7]	4,400[8]	2.6	43.0	0.7	37.0	0.6	3.9
Urban railway (22,500 passengers per hour)	30	1,700[7]	1,600[8]	0.9	43.0	0.7	37.0	0.6	2.2

(1) This column is adapted from Professor R. J. Smeed's presentation in "The Traffic Problem in Towns" (Manchester Statistical Society, 1961), with the data on road capacities updated by him on the basis of more recent work by J. G. Wardrop. PCU values assumed

	Urban Street	Expressway
Car	1	1
Taxi	1	1
Minibus	2	1½
Bus	3	2

(2) Track costs per hour, which are subject to wide variation, have been calculated on the basis of a 2,000 hour per year track utilization, infinite track life, and a 12% per year interest charge. Figures given are for a strip one mile long and one foot wide. Urban street is assumed to cost US$240,000 and urban expressway US$1,800,000 per 12 foot lane mile, inclusive of land and all services. Capacity of expressway is assumed to be 2,200 PCU per lane per hour.

(3) Maintenance costs are assumed sufficient to keep track in good condition indefinitely, and also include the costs of lighting, cleaning and traffic control. Figures are based on data collected by Alan M. Voorhees and Associates in the Bank financed Caracas Road User Charges Study.

(4) Vehicle operating costs, which include depreciation and interest charges, are also subject to wide variation. The 13 cents a mile for a car represents a U.S. "compact" car under relatively favorable road conditions. Taxis are assumed to have the same costs as cars plus drivers' wages of 70 cents an hour. Minibuses are represented by the 14 seat Hong Kong "Public Light Bus" and costs are adapted from Richard Butler's *Bus Operation in the Colony of Hong Kong*. Bus costs are assumed as in Kuala Lumpur's 40 seat buses as calculated by Wilbur Smith and Associates. Railway operating costs, which relate to London, are supplied by London Transport. Speed reductions from 15 to 10 miles per hour are assumed to raise operating costs by 12% in the case of cars and taxis, 15% in the case of minibuses, and 20% in the case of buses. Speed rises from 15 to 40 miles per hour are assumed to result in vehicle operating cost savings of 15% in all cases.

(5) Data on footways are obtained from "Movement of Pedestrians on Footways in Shopping Streets" by S. J. Older, *Traffic Engineering and Control*, August 1968.

(6) Mixed traffic on urban streets are assumed to move at 15 or 10 miles per hour. Taxis are assumed to stop 1 minute, minibuses 2 minutes, and buses 3 minutes per mile traveled.

(7) Bus on expressway figures are based on observations on the I 495 bus line leading to the New York Port Authority bus terminal, recording 597 buses in one hour. Higher rates of flow were observed over five minute periods. Railway passenger flows are based on conditions on Mexico City's Metro; overall average loadings are assumed to be 62 people per car compared with 16 in London. These volumes should not be taken as maximum capacities of mass transport; passenger flows in excess of 60,000 per hour have been observed in New York and Tokyo subways, under conditions of crush loading. Similar volumes of passengers, even all seated, could be moved by high capacity buses on exclusive lanes. Few traffic corridors generate such volumes.

(8) Metro track is assumed to cost US$8,000,000 per lane mile, as in Mexico City. Urban railway line is assumed to be at ground level and to cost US$3,000,000 per lane mile.

Moreover, these buses are frequently old and in bad states of maintenance due to the political necessity to keep fares low. Partly because of low capital costs, partly due to low driver wages, and partly due to the greater vehicle occupancy, costs per seat-km are maintained at levels from $0.02 to $0.10.

The hidden price is in the poor levels of service particularly during the morning and evening peaks, when waiting time can extend to one hour to board the bus. Lack of service is particularly felt by the urban poor, and many of the squatter settlements are not served at all. Often this is the result of inadequate roads into these areas.

The state of maintenance is thus a significant problem. The World Bank [6] has estimated that up to one-third of the municipal fleet may sometimes be immobilized because of poor servicing and maintenance compounded by the low speeds due to congestion.

The low quality of bus services has led to the development of private, "intermediate" transport services in many Asian and African cities. These minibus and jitney services fill the wide gap between the bus and the taxi, generally charging fares about twice that of the bus services.

Non-Motorized Transport

One of the explanations for the small number of buses per inhabitant in the poorest cities is that a large portion of the population is so impoverished that even the low bus fares would consume 10% of their income for the round trip to work. At this level of income, less than 1% is normally allocated to transportation.[5] These families therefore are far from able to use any form of public transit. It is estimated that up to two-thirds of the residents in many African and Indian cities walk or ride bicycles.

Facilities for pedestrians and cyclists are bad, and becoming worse, as sidewalks are cut back to make way for motorized traffic. Seldom are any provisions made for street crossings,

and safety crosswalks and lanes are generally ignored by motorists. The accident and fatality rates are high and fall mostly on pedestrians and cyclists.

Commercial Traffic

In the poorer cities, commercial traffic probably makes up almost a third of the total. The high level of congestion is very hard on this traffic because of wear and tear on engines. The presence of barrows and animal carts in the traffic mix is particularly costly for commercial transport. Compounding the difficulties are the absence of adequate warehouses and terminal facilities for the breaking of bulk. Markets located in the center of town cause much of commercial traffic to come to a standstill during many hours of the day.

Cost of Urban Streets

As a city grows it eventually becomes necessary to widen main access routes and possibly some of the streets in the center, simply because the denser the population the greater must be the percentage of land given to roads. This, however, is very expensive. World Bank estimates (1975), as indicated in Exhibit IV-1, are $150,000 per lane-kilometer for urban streets and $1,125,000 per lane-kilometer for urban expressways. At these prices, a round-trip toll to cover the costs for an expressway would exceed $0.05 per vehicle-kilometer, assuming capacity use. Because of the much lower capacity of an urban signalized street, the equivalent cost per vehicle would still be about $0.03 per kilometer.[6] For the largest of the cities, particularly those which are forced by natural barriers into linear patterns, metros can become attractive as an alternative to private automobile track. Although the capital costs are about five times those of expressways (See Exhibit III-1), because of its extremely high capacity, the per-passenger cost is about half that of the private automobile. However, for most cities a metro is considered to be a poor alternative to a high capacity busway, which can carry a greater number of passengers per hour at capital expenditures less than those for an expressway.

Limited Financial Resources

While road construction is expensive, adequate financial resources to make improvements are usually not available. Transport investments frequently consume from one-fifth to one-quarter of total urban budgets. In Bombay this represents 2% to 3% of the per capita income of a population which allocates less than 5% of family income to transport use; yet this only amounts to $5 a head.

Much of this investment is directed to improving road capacity. As a result the main effect has been to accommodate more private automobiles, and little of the benefit is experienced by the urban poor.

The foreign exchange cost may not yet be excessive. In 1975 it was about 5% of all imports, mostly on private automobiles. However, due to the growth rate of the vehicle fleet this will have doubled by 1985. Of the foreign exchange required for private automobiles, about one-third is for fuel. On a per-passenger basis, an automobile passenger uses almost ten times the fuel of a bus passenger.

Planning, Management, and Coordination

A number of organizational factors inhibit good planning, management and coordination [1]. The primary one of these is that responsibility for the various aspects of transport is generally in separate agencies [8]. Construction is often in the Public Works Department, and the agencies for administration of buses, railways, ports, and markets are almost always separate and frequently fiercely autonomous. Accordingly it is normally difficult to coordinate plans.

This is especially important because of the political pressures on local transport decision-makers. This comes about because car-owners in developing countries come from the wealthy and influential members of the society, whereas bus riders come from the poor. Accordingly, any policy which would favor buses

and discriminate against cars would alienate the people who have significant political power. On the other hand any attempt to raise fares is likely to also bring loud public outcry. For these reasons such unpopular decisions must normally be undertaken in coordination with other measures which can be clearly seen to be beneficial.

One of the most common problems is in the difficulty of enforcement of traffic regulations. The police forces are often undermanned and view traffic control as a low priority. Furthermore, the police are usually in a different ministry than the one responsible for transport planning with the result that lengthy negotiations are required to obtain any changes in traffic regulations.

General Principles

Conservation of resources and the reduction of travel time are both desirable consequences of transport planning, but they are not necessarily jointly achievable. In particular, if the goal is to provide transportation to the population which currently walks, then this can only be achieved at the expense of fuel conservation. However, many of the decisions that transport planners can make are conducive to both goals. The following are the policies currently favored by the lending organizations [1,5,6]:

- Reduction of Congestion Through Traffic Management. There are a large number of traffic engineering measures which can greatly increase the capacity of existing streets and to guide their utilization of more efficient uses. The congestion reduction techniques not only reduce travel time but increase the fuel efficiency of vehicles as indicated by the following table.

Fuel Consumption as Function of Speed (liters/km)

	5 kph	10 kph	20 kph
Automobiles	.154	.104	.078
Light Goods Truck	.305	.190	.132
Heavy Goods Truck	.286	.196	.156

Although average speeds as low as 5 kph occur only under the most congested conditions, speeds in the range of 10 kph are quite common. At this level, a 1% increase in average speed generates a 1% reduction in fuel consumption.

- Shift from Private to Public Transport. At first sight, this appears to be a virtually impossible goal given the preferences of the automobile owners. Certainly there is small chance that the car owners can be persuaded to board a crowded vehicle which travels even slower than his car. Only when the bus is perceived to be both reasonably comfortable and faster than his car will the car owner willingly use public transport. Thus in order to achieve the long range goal of work trips taking place by public means, busways or other privileged operation will eventually be required in all large cities. In the meantime, pricing measures have been found to be effective in encouraging the formation of car-pools and shared taxi ridership. Dedicated high occupancy vehicle lanes have achieved beneficial results in developed countries.

  At the other frontier, the policy to extend public transport to the urban poor is contrary to fuel conservation and must be justified on social grounds. However, unless fare subsidies are made, this will only increase public ridership slightly. Much more beneficial, and certainly fuel conservative, would be to improve facilities for pedestrian and especially bicycle travel.

- Labor-Intensive Construction and Maintenance. Because of its introduction via the developed nations, road construction and maintenance have historically been capital intensive. This was especially true during the period when modern roads were constructed by contractors under colonial regimes. As a result the current state of road maintenance is generally poor, and the equipment largely in a non-operational state.

Much research by the World Bank and the International Labor Organization [36] in the past 10 years points to economies to be gained by using labor-intensive methods. Not only is this resource conservative (both of capital and fuel), but this also provides employment.

- Improvement in Urban Form. Transportation and urban form are closely related. Historically the provision of transport infrastructure has followed the existing urban form, reinforcing the radial structure and eventually exacerbating the transport problem. Lending institutions are currently funding transport projects which hopefully will result in an urban form which shortens, rather than lengthens, the average trip distance. Achieving future industrial growth requires efficient and systematic balancing of the complex interactions among transport, land use, and energy conservation.

TRAFFIC MANAGEMENT MEASURES

Traffic management is the science of increasing the traffic handling capacity of the existing street system as opposed to expensive infrastructure investments to increase the total urban capacity by widening old streets or building new streets and overpasses; as a result it is often thought of as a temporary measure. But traffic management techniques can increase capacity by 50% and higher [11]. Because of their relatively low cost they have a very much higher rate-of-return than road construction projects. Traffic management is a set of empirical techniques which are based broadly upon the following principles:

- Separate Access From Mobility. Roads serve two basic functions -- access to activities (at the roadside) and mobility from one activity to another. These functions interfere with each other and should not be mixed. In practice it is desirable to have step-down streets ("collectors") which are intermediate between high mobility roads ("arterials") and local streets.

- Reduce Traffic Conflicts. Traffic conflicts occur whenever vehicles share the same facilities and mismatch each other in some operational characteristic. Vehicles with different speeds, vehicles travelling in opposite directions, vehicles which are crossing each other's paths, and vehicles travelling while others are parked are all cases of traffic conflict. The more a traffic management scheme can

reduce conflicts, the greater will be the capacity of a street.

- Increase Vehicle Occupancy. The more intense the demand for arterial capacity, the greater must be the use of high-occupancy vehicles. This leads to a hierarchical regulation of traffic as the center is approached. As a corollary to this, wherever possible vehicles should be guided around high intensity traffic areas and discouraged from passing through.

In the remainder of this section a number of traffic management techniques are described. Most have been intensively applied in the cities of the developed world but are only recently being adapted to Third World cities.

Traffic Engineering Actions

These are the class of actions which change the use of streets in ways to reduce traffic conflicts.

- One-way Street Systems. In urban street patterns which are gridded these often reduce accidents and travel time by 20% or more [11]. However in complex street systems a detailed turning movement study should be made first.

- Restricted Turns. Left turns may be prohibited on major arterials except for occasional cross-streets. This requires a careful traffic study, however, because it can result in increased travel time at some locations. In many cities, turns are prohibited during rush hours only.

- Reversible Lanes and Left-turn Lanes. The center lane(s) of a street can be used for incoming traffic in the morning and outgoing traffic in the evening. This can increase capacity by 50% [11]. During the day such lanes can be used as left-turn lanes where vehicles wait outside of the main traffic flow for a break in oncoming traffic.

- Intersection Channelization. There are a large number of minor, inexpensive changes which can be made at intersections to guide traffic into channels which encourage smooth turning movements and reduce accidents. These include traffic islands, turning or loading bays, and rumble strips. In complex street systems with many intersections, minor reconstruction to alter the intersections or widen parts of the

street can have major benefits. These require careful analysis, however, and it is difficult to generalize.

- Flyovers. At major intersections, flyovers can be installed. However, these should generally be implemented only at intersections with ring roads and in the circumferential direction, so that the radial route continues to be signalized. The purpose is to make the bypass route faster than the radial in order to discourage trips through the center and to encourage penetration of the center from the point on the circumference which is closest to the destination.

- Signalization. Traffic signal lights are considered to be warranted when the intersection traffic rises to between 500-1000 vehicles per hour. Most signals are manually pretimed, based on historical flows and can change cycle timing during the day. Since the purpose of traffic lights is to maximize traffic flows by batching traffic through the intersection, the lower the volume, the shorter the cycle time should be. At off-peak hours, many traffic systems in the developed cities switch to traffic actuation. This expensive step, however, is not essential and an alternative is to set the lights to flashing yellow or red.

  When the city is large enough to have many signals, it becomes effective to coordinate them, particularly on major arterials or one-way street systems. Most large cities use computer control. This has proven to reduce travel time from 10% to 20% below that in uncoordinated systems. Analyses indicate that computerized networks are economically viable for networks with over 50 signals [11].

Separation of Transport Modes

These are actions which separate vehicles by the mode of operation or by operating characteristics.

- Preferential Treatment for High-Occupancy Vehicles. These are techniques designed to maximize the passenger-carrying capacity of road space. The most common form is the reserved bus lane in the with-flow direction of traffic. Generally, these lanes are given priority at signals, which allows them to bypass cars queued there. Reductions in travel time range from 5% to 40% [11]. Contra-flow bus lanes are sometimes employed in short sections of one-way street systems.

Exclusive busways have only been developed in the past 10 years. However they support speeds of 50 to 60 kph and have the greatest passenger capacity of any transport system, including metros. As seen in Exhibit III-1, this mode has the lowest cost of all forms of transport. Furthermore, they can appeal to automobile owners if first-class buses are included.

In most of the cities in the developed world which have bus lanes or busways, four-passenger car-pools and van-pools are permitted to share these priority facilities. As can be seen from Exhibit III-1, such vehicles have about half of the carrying capacity to share a pooled vehicle than to ride a bus. In a number of cities, park-and-ride facilities are provided. If however, parking in the downtown area has become extremely difficult or expensive, half of its advantage is gone. Under such circumstances, a high-speed bus service can increase its utilization by the addition of parking lots.

- Facilities for Pedestrians. As seen in Exhibit III-1, footways have a higher "passenger" capacity than any form of transit other than busways or metros. Yet historically, footways and sidewalks have been steadily eroded to make way for automotive transport which has the lowest carrying capacity. As a result, pedestrian traffic tends more and more to interfere with motorized traffic. At very low capital expense, pedestrian ways could be separated from vehicular traffic to the benefit of both. Such pedestrian ways could be created by barring motor traffic on small streets parallel to the main throughfare and vice-versa. Aside from low surfacing costs the most important investments would be crosswalk signalling, and over- or under-passes. Covering the walkways is an investment which could also pay handsome rewards to developing cities. Not only would this slow down the shift to bus but would tend to move most trading activities away from the arterials. To date, no cities have implemented walkways in a comprehensive manner; however, Nairobi has plans to improve 90 km of footpaths.

- Facilities for Bicycles. Similarly, improvements to bicycle tracks will delay the transition to motorized transport. While special bikeways could be created on parallel streets, it would be difficult to restrain conflicting pedestrian uses. Therefore bicycle lanes are usually marked off at the side of motor routes. Because a 1-meter bicycle lane can carry almost as many passengers as each vehicle lane, this is usually adequate. To improve safety for cyclists, however, physical barriers can be emplaced

between the bicycles and vehicles. The most difficult problem for bikeways is their intersection with streets, especially in the central area. Japan has invested considerably in bikeways and by 1976 had almost 15,000 km. The Japan Bicycle Association has produced a manual of design standards for bicycle tracks [13].

- Slow-Moving Vehicles. A special problem is animal carts and human powered vehicles. The former are hard on both the road surface and other motorized traffic. Due to their size and speed they are assumed to have a pcu equivalence of 6 vehicles. When motorized traffic becomes intense, animal carts should not be allowed to enter. At the same time, the markets to which they normally are moving should be relocated to the outskirts of the city.

  Rickshaws are not as much an interference as carts, but both types of vehicles have extremely low capacity, hence their inclusion on arterial streets is not beneficial. Increasingly, rickshaws are being banned from the principal streets, and they are on the wane in most cities.

Influencing Access to Central Areas

These are actions which tend to discourage traffic from entering the main activity centers during peak hours.

- Parking Restraints. In the not too recent past, parking policies were such as to favor long-term daily parking over short-term shopping uses. Thus store employees and commuters parked on the street while shoppers had to park off-street or at some distance. This is now recognized as contrary to rationale use, as it impairs both the access function and the mobility function, due to street parking during peak hours.

  In the central area, parking restraints should be both regulatory (prohibited during peak hours) and economic (no discount for long-term use and metered to require frequent feeding). Simultaneously, however, provisions should be made for inexpensive parking by outlying locations with shuttle service to the center.

  The prohibition of rush hour street parking can be combined with bus preference measures, using the freed-up space for buses only. During normal hours buses and automobiles share the central lanes.

- Physical Entry Inhibitions. Many downtown shopping areas in developed cities have successfully implemented a pedestrian-only mall, sometimes with a circulating shuttle bus. After initial resistance these malls are favorably viewed by both residents and shop owners. A successful example of this concept is in Curitiba, Brazil. Other cities have implemented schemes to separate local residential or shopping "zones" from arterial streets, either via unfavorable signal sequences or by physical barriers to prevent access between the arterial and most of the local streets of the zone. Traffic can circulate freely within the zones but can enter the arterial system of streets only at certain points. Similarly it is difficult for through traffic to traverse a zone. Examples of this system are Gothenburg, Sweden and Bremen, West Germany.

- Pricing Inhibitions. There are three potential methods of levying a charge for the use of congested areas: tolls, parking charges, and area-use permits. Of these, tolls are seldom possible due to the congestion which such a facility itself would cause. Parking charges and area-use permits are more or less equivalent. An extremely successful example of area-use permits has been demonstrated in Singapore. The Singapore restraint requires that any car entering the restricted zone during the morning rush display a permit window sticker.

- Staggered Work Hours. By staggering work hours, the demand for commuting trips can be smoothed. More than one-third of large American cities use this device [3] to reduce the peak. Many companies achieve this through flexible work hours. A more common method is to have government work hours begin and end two hours early. Similarly, schools can be scheduled to open earlier than the rush. When this is done, buses can double for both school and worker commuting.

- Restrictions on Truck Deliveries. Because of the small physical size of many urban goods deliveries, commercial traffic makes inefficient use of urban road space. In one urban study in the U.S., it was estimated that deliveries to the stores could be made with fewer than 1% of the number of pickup trucks actually in use [11]. As a result, in many cities commercial traffic is prohibited from entering the downtown during the peak hours, or in some cases, during any daylight hours. While this might appear to penalize commercial vehicles, in fact any increase in salaries is more than compensated for by the reduction in vehicle operations costs and by the fact that the movement of goods takes far less time.

- Truck Terminals. Most of the cities in the developing world do not have adequate terminals for the breaking of bulk. Establishment of such terminals at the periphery of the city would allow the distribution to stores in the city to be made by much smaller vehicles.

PUBLIC TRANSPORT

Service Categories

Public transport in most Third World cities falls into three categories:

- Taxi. Characterized by intermittent nature, complete flexibility in the destination chosen by the passenger. Fares are normally proportional to distance and on the order of 5% of average per-capita daily income for a 3 km trip.

- Bus. Characterized by fixed service, fixed-route, typically very crowded. Fares are in the order of 1% of average daily income for a 3 km trip. In some cases these fares are fixed, in others proportional to distance.

- Intermediate Public Transit. Because of the wide gap between the crowded bus and the expensive (and slow) taxi service, there has sprung up in most Asian and African cities private transit operations which offer public transit intermediate between the bus and the taxi, generally at flat fares approximately double that of the bus [23,25,25].

Intermediate Public Transport

A great deal of controversy has surrounded this intermediate mode, and occasionally they have been banned, mainly due to lobbying by bus companies. They are, however, popular and have variously captured from 10% to 90% of the trade in different cities [19,22].

Intermediate public transport services usually rely on minibuses or small pickup trucks which have been converted to passenger use by placing two benches along the sides. In some cities even smaller, three-wheeled trucks are used (e.g., the bemos of Surabaya, Indonesia).

The service is most often of the jitney type, with routes fixed but with stops at any point. Often the services emanate from a central terminal so they do not leave until full. However, "curb-crawling" to attract trade is a complaint levied against some services. Furthermore, the drivers sometimes drop riders at most convenient locations off the normal route, especially at the out-of-city end of the route, and circulate to obtain returning custom. Conversely it is not uncommon for drivers to reverse direction before the end of the route if their vehicles are almost empty.

Because of their smaller size, these jitney vehicles can and do circulate in among the narrow streets of the city, thus providing a collector service. However they also compete directly with the standard bus services on the main routes. Because they normally load up quickly and make much fewer stops than the large bus, they are always faster. For example, during off-peak hours the jeepney travels the central corridor of Manila at 20 kph while the bus travels at 15 kph [22]. Similarly in Chieng Mai [23] the silor travels 50% faster than the bus. Passenger opinion surveys generally indicate speed and comfort as the reasons motivating their choice of jitney over the bus.

It seems clear that jitney services serve an important function in Third World cities where it is necessary to continue to provide low quality but inexpensive service to the poor via the standard bus. Although mainline bus operators charge that they give unfair competition, it is apparent that they are attracting a different market. In order to serve this market, more buses would have to be supplied, and (at the same fare) would not contribute to the bus profitability since some jitney drivers take their vehicles out of service during off-peak hours, thus smoothing out peak bus requirements. Peculiarly, this balancing function is sometimes a subject of complaint -- the objection being that jitneys take the "cream" of the demand.

Private transportation is almost always more cost-efficient at any given level of service than public transport in the

developed as well as the developing world. Walters [3] argues that the difference is as much as 50-65%. Data from a sample of Asian cities [27] show that the cost per seat mile is 2.3 times greater for publicly owned bus companies than for privately owned companies. The principal reason for this in the developing world is staffing and driver salaries. Municipal bus services have staffs ranging from 3 to 10 vs. 1 to 2 for the private, usually one-vehicle, firms. However, it is generally agreed that the privately owned vehicles are better maintained. Finally they do not operate at hours during which there is low ridership.

Vehicle size also affects economy. All privately owned transport companies use small vehicles. Even though these vehicles have lower fuel efficiency, this is offset by the decreased capitalization costs vs. a large bus. Data from a cost study in Manila comparing the 14 seat jeepney to a 58 seat bus [31] show that the capitalization costs of the bus are approximately twice that of fuel costs, while the opposite is true for the jeepney. If both vehicles are fully loaded, the costs sum to the same amount.

In general, it is difficult to assemble cost data on buses and minibuses on a comparative basis, but it appears likely that small vehicles are in fact much more capital conservative than shown in the available studies. For example, most such comparisons use service lives of 12 years for buses and 5-7 years for smaller minibuses and vans. Yet it is apparent that these vehicles last far longer in practice.

Furthermore, because such private transport is profitable, there is much competition. Also, with short headway between jitneys it is clearly easier to maintain a high load factor for the smaller vehicle. Therefore, even though it is true that fuel economy is maximized with a large vehicle, free competition drives the optimal size down, as is clearly evidenced by the size choice made by the transport entrepreneurs.

Transport in Small Cities

In general, the intermediate public transport services in the larger cities operate with high load factors and on fixed routes. An analysis of these services in two smaller cities, Chieng Mai, Indonesia and Tacloban, Philippines, indicate that in this environment, transport services can operate at very low load factors and still be profitable. The Chieng Mai silors (small minibuses) offer a shared-ride taxi service, taking the rider to any destination. In practice the load factor is so low that much of the time a passenger has the vehicle to himself. Chieng Mai has a population of 100,000 and the average trip distance is only 1.2 km. At this distance, fixed-route service is not popular. Only 7.5% of total trips are made by bus even though the fare is half that of the minibus. Furthermore, the buses are uncomfortable and only half filled.

This experience is instructive about behavioral choices. A fleet of 200 buses could satisfy Chieng Mai's transport requirements with 4 minute headways and guaranteed seating (currently Chieng Mai has 50 buses). Instead 2,000 minibuses provide 30 second headways. In a survey at Chieng Mai, approximatley 90% of respondents stated their selection of the minibus was because of convenience and speed, while 73% of the bus riders stated that fare was what motivated their choice.

The situation in Tacloban is not quite as extreme, but there are 500 jeepneys for a similar population. Assuming that the rate of trip-making is similar to that of Chieng Mai (300,000 trips per day), then the average load factor would be on the order of 25%, and the average wait for a vehicle about two minutes.

If the experience of Chieng Mai is any guide, the introduction of buses in Tacloban would probably attract very few customers except from the very poor. It is unlikely that (except through legislation) that any jeepneys would be taken out of circulation.[8] Furthermore, the capacity of the vehicles in Tacloban does not appear unreasonable for a town of 100,000. If

the 500 jeepneys were to be replaced by 125 50-passenger buses, for instance, the average waiting time for a bus would be multipled by four. It may seem that the fuel consumption is excessive, but this must be put into perspective. Based on Tacloban's traffic counts, private automobiles account for 40% of the fuel consumption, or approximately 12 liters per vehicle per day, while public vehicles consume 50% or 60 liters per vehicle per day. However, this amounts to about one liter per head of population, or 1/12th of the amount consumed by the car owner.

Certainly it is desirable to avoid the kind of fuel consumption which was occurring at Chieng Mai in 1977, but this can be accomplished better by limiting the entry of new vehicles into the system if the problem becomes acute.

High Fare Public Transport

Taxi services are currently the only mode of public transport used by the wealthy (car-owning) population. In Asian cities this is principally via rickshaws. These are currently being seen as inappropriate to the city since they are disruptive to traffic. They are banned in many large cities and it is not expected that they will survive many years.

In the long run, if not already in many cities, the most pressing problem will be to persuade the car owners to use high occupancy vehicles. Car-pooling, van-pooling, and park-and-ride stations for buses on preferred lanes or busways have been the most successful methods employed in the developed cities. Reserved bus lanes are being used in over 50% of large North American and European cities. Another method which has been successfully implemented in Rio de Janeiro is charter subscription bus services using first-class (comfortable seating) buses.

Unusual Vehicles

One of the outstanding features of transport in Asia is the unusual, and generally small, vehicles [26,28] such as the

becaks, bemos, opelets, helicaks, super helicaks and pickups of Jakarta, and the freight tricycles of Penang. When used as taxis, these small vehicles are very beneficial to Third World governments, since they are so fuel conservative relative to full-sized saloon cars.

Freight, tricycles in Penang have a large metal box between two front wheels, cost about $175, and number about 3,000. They are ideally suited for Penang's narrow streets. They can efficiently carry loads of up to 200 kg. for distances up to four kilometers.

In Manila and Tacloban, among the unusual vehicles is a bicycle with a sidecar powered by a 50cc two-stroke engine mounted in the cycle frame. This drives the rear wheel through an additional chain drive, the original pedal chain drive being retained so that the rider can augment the power of the engine when necessary.

In China, many of the minor roads and tracks in the rural areas are narrow and unsealed but are quite satisfactory for the types of vehicles which travel on them (bicycles, handcarts, wheelbarrows, and two-wheeled tractors).

The Chinese have shown considerable innovation in the design of tricycles for proper gearing and effective braking. In very poor areas in tropical climates tracks are sometimes used for worker commutation. Although we know of no examples, it would seem to be a good idea to offer a very low-cost service in buses with no windows (open air) and no seats with grab-bars and vertical stanchions.

LABOR-INTENSIVE CONSTRUCTION AND MAINTENANCE

In the developing world, many of the urban streets and rural roads are unpaved. The benefits of paved versus earth or gravel roads are considerable. The vehicle operation costs on gravel roads are 50% greater than on paved, principally because of increased depreciation, parts and tire wear (fuel use being only

slightly affected), and the same ratios exist for operation on badly deteriorated pavement versus rehabilitated pavement. If traffic on an urban street is only 1,000 per day, the annual benefits in vehicle operation costs for having well maintained streets would be about $20,000 per kilometer.

Since the cost of maintenance should be around $3,000 per kilometer, it is clear that a good street maintenance program pays very high rewards [37]. Yet typical road maintenance programs, at least for rural roads, allocate less than $300 per kilometer per year. Because many roads were originally constructed under colonial governments, most maintenance organizations use highly capital intensive methods, and by now much of this aging equipment is more-or-less permanently out of service.

For the past decade, the International Labor Organization and the World Bank have been conducting studies to compare labor intensive road construction and maintenance technologies [32,35,36]. Many of these experiments have been carried out in the Philippines [38]. The scope for labor intensive methods is considerably greater than most planners have been aware of. Based on these methods, urban roads could be improved and maintained with a very low foreign exchange component and paid for by a tax of 10 cents per liter. This report will not describe the particular techniques recommended, but they are available from the World Bank (the following is a list of the particular studies which have been conducted).

Number	Title
1.	Comparison of Alternative Design Wheelbarrows for Haulage in Civil Construction Tasks
2.	Increasing Output of Manual Excavation by Work Reorganization: An example of Passing Place Construction on a Mountain Road
3.	Comparison of Different Modes of Haulage in Earthworks

4. Effect of Health and Nutrition Status of Road Construction Workers in Northern India on Productivity

5. Comparison of Hand Laid and Machine Laid Road Surface

6. Haulage with Lift of Materials: Lifting Sand by Ropeway

7. Productivity Rates of Earthmoving Machines

8. Collection of Productivity Data from Civil Construction Projects

9. Report of First Road Demonstration Project

10. A System of Deriving Rental Charges for Construction Equipment

11. A Literature Review of the Ergonomics of Labor-Intensive Civil Construction

12. Haulage by Headbaskets, Shoulder Yokes and other Manual Load Carrying Methods

13. The Use of Wheelbarrows in Civil Construction

14. Hardware Research Summary

15. The Planning and Control of Production, Productivity and Costs in Civil Construction Projects

16. Level Cranes

17. Compaction

18. Spreading Activities in Civil Construction

19. Excavation

20. Loading and Unloading Activities

21. A Literature Review of the Work Output of Animals with Particular Reference to their Use in Civil Construction

22. Haulage Using Aerial Ropeways

23. The Use of Rail Systems in Civil Construction

24. The Use of Agricultural Tractor/Trailer Combinations

25. Aggregate Production

A successful road maintenance program in Kenya has been reported which assigns particular lengths of the road to individual contractors called "lengthmen." Since each contractor is well known in the community, this leads to peer pressures to perform the contracted maintenance well.

ACCIDENTS

The Transport and Road Research Laboratory has been carrying out investigations on accidents in the developing countries since 1972 [39,40,41,42,43]. While the accident rates are somewhat higher than those European cities, the fatality rate is almost 10 times as high (and 20 times the rate in the U.S.). Moveover the cost of accidents to developing nations is very large -- on the average almost 1% of their annual gross national product.

A large percentage of the fatalities is suffered by pedestrians and cyclists. Additionally, data show that accidents to these classes of road users occur proportionately higher in central areas, in comparison to England. An analysis of driver behavior in various cities indicates that there is considerably greater tendency for drivers to take chances in developing cities. The percentage of drivers choosing to ignore a red traffic light was very much greater than in England (although two studies in Nairobi in 1975 and 1977 showed a significant improvement). Similiarly only 10% to 20% of the drivers in most of the developing countries stopped for pedestrians within zebra crossings (0.2% in Surabaya!), as opposed to 40% to 70% in England. Conversely a relatively high number of pedestrians jaywalk in Surabaya in comparison to data from England.

Accident reduction measures, such as zebra crossings, road markings, signing and improved skid-resistance surfaces have been shown to be highly cost effective in reducing accidents in the U.S. and Europe. However, it appears that for them to be effective in the cities of the developing world will require considerable enforcement and education.

PLANNING

Models

The planning of transport improvements in the cities of the developed world has frequently involved the use of computer models. At least one-third of the cities in the U.S., for example, made use of the UTPS planning package during the decade of the 70's. The application of computer models to the cities of the developing world, however, is currently being discouraged by the World Bank and the other critics [48,54,55] for the following reasons:

- Cost. A great deal of data must typically be collected. The period to prepare and execute the model is often two years. The total cost may exceed $500,000.

- Structural Weaknesses. As summarized by the World Bank [6], "Conventionally urban transport models, moreover, have basic weaknesses which stem largely from the intricacies of the transport network, the complexity of the factors influencing demand, and the sequential treatment of influences which are, in fact, interdependent. Congestion charging and other policy variables cannot be readily introduced, nor can the extent of suppressed demand and effects on traffic of acute congestion. In brief, the models are poorly adapted to major changes of urban form, function and transport modes."

- Rapid Change. In the U.S. and Europe, city populations grow only a few percent a year, whereas developing cities may double in size in only 10 years. The forecasting methods of the standard transport models are predicated on the basic driving forces (traffic generation) remaining very similar to the current conditions.

- Bias Towards Infrastructure Investment. Most planning models assume that traffic demands are fixed (inelastic to supply), and are oriented to overcoming bottlenecks. Thus they assume that the problem is solved when sufficient street capacity can be provided. The result is generally to recommend the building of roads which primarily benefit the car-owning class. Not only is this questionable from a social viewpoint, but it ignores a fundamental "law" of urban development -- that urban populations move

to residences which are made accessible. Thus investments to remove bottlenecks often have the result of increasing congestion after a few years.

Transport Infrastructure And Urban Form

Fundamental Dynamics of Urban Growth

The physical pattern of most large cities in the world is characterized by a central business district which contains a high proportion of the jobs surrounded by a number of dense radial spokes of residences and shopping.

This is basically a result of the manner in which transportation affects the development of urban form. The relocation of families and firms is based on thousands of individual decisions which take into consideration many factors directly or indirectly affected by transport. In the central district, virtually all land is devoted to commercial, transport or public uses, because these uses are the most productive on a per area basis and require a great amount of face-to-face contact. The competition for land forces residential and industrial uses to relocate on less expensive sites outside of the central business district.

Because of the need to reduce their transportation costs, when industries move they generally relocate along principal road and rail access corridors of the city. In the cities with low private car-ownership ratios, because of the dependence on public transit, residential development also takes place along these main radials, resulting in an urban shape of long, heavily congested tentacles. Small towns along interurban highways and railroads also begin to grow rapidly as the development from the primary city approaches them.

However, when the per capita income rises sufficiently, so that automobile ownership becomes significant, a marked shift occurs. The existing street capacity soon becomes unable to absorb the increasing vehicle fleet, and the city begins a period of rapid expansion into the land available between the major corridors.

If this expansion is not orderly it carries the threat of two serious urban problems:

- Urban Sprawl. Unless active steps are taken to assure the creation of satellite activity centers (e.g., industrial parks, shopping centers, and integrated residential areas), land development will take place by small additions at the periphery of the already developed portion. The result is not only unattractive, but inefficient in terms of transportation.

- Deterioration of Public Transit. Dispersed, non-integrated residential development on the periphery of the city makes servicing by public transit expensive and inefficient. Under these circumstances, there is a continuous transfer from public to private transport. The reduction in patronage and the loss in revenue force the public transit companies to diminish the quality of service, thus accelerating the transfer from public to private transit.

Goals for Urban Highways

Many of the smaller cities in the developing world are entering a period of rapidly expanding automobile ownership. City populations may be expected to double within 10 to 15 years. Accordingly it becomes extremely important to plan carefully and to guide the investments in roads so as to achieve urban forms in which transport is not such a major problem. Although the geographical conditions peculiar to each city make it impossible to define the optimal urban form, several goals can be stated.

- Ensure Proximity Between Work, Residence, and Shopping. Neither the dense central district nor urban sprawl are conducive to this goal. Ideally it should be possible to accomplish many of the daily trips on foot or by bicycle so as to reduce the pressure on road space.

- Ensure Rapid Freight Movements. Most cities have their origin as goods movement centers -- ports or markets. Access to these centers should be improved so as to encourage the relocation of industry outside the dense city center, particularly in geographically constrained cities. If possible, special routes should be built.

- Discourage Movement Through the Center. As the city grows, a system of high capacity, high speed ring roads should be developed.

Activity Centers

Urban planners have long been recommending that expansion of the city take place in satellite activity centers located outside of the current urban perimeter, and many examples of this development philosophy now exist in Asia. One of the most successful is Singapore with already eight subsidiary centers [3]. As a general rule, very few businesses require location in centers of over 100,000 population. But because relocation decisions are made by hundreds of small businesses, such expansions must occur in quantum leaps. The proposed new center must be seen as nuclear to a businessman and likely to expand quickly, otherwise he will not be willing to risk the move.

Promotion of new centers requires actions at several levels in an integrated plan. The following factors should be provided:

- Quick Access to the Main Center. High speed transportation should be provided to the old center. This is particularly important if the city is a transport terminus, such as a port. However, care must be exercised to make sure that this doesn't accentuate congestion on these routes. Roadside uses should be applied to automobiles. Busways would be recommended.

- Proximity to Existing Populations. Employers and shopkeepers need employees and customers. As a result this usually restricts potential locations to points on the main arterials to the old center. However, this leads to a potential future problem -- that traffic to the old center from the outside will travel through the new center. One solution is to build a ring road and to site the new center near but not on the intersection. Another is to create a bypass commercial route. A third is to simultaneously build a residential complex by the new commercial center.

- Essential Urban Services. Adequate water, sewage, power and other essential services must be provided. Often preferential taxation is used to encourage relocation.

- Nuclear Activities. Most businesses can be more easily induced to relocate if some large nuclear activity is seen to be relocating. This may be a large industry, or a central food market. One possibility is to move some or all of the governmental services.

SOME EXPERIENCES

In this section, a few case studies are briefly mentioned. Unfortunately, although there is a wealth of material describing experiments in traffic management and public transport in cities of the developed world, very little has been reported of Third World experience in these areas. However, there are a considerable number of projects currently underway in Asia and Africa, funded by the World Bank. As yet, no formal documents have been published reporting the results, but officials of the Urban Projects Division of the World Bank may be contacted for informal discussions.

Singapore Traffic Restraint

In 1975 the city of Singapore introduced an area-use permit system within the central district which is surrounded by a ring road (See [9, 15] for extensive descriptions). In order to enter the restricted area between the hours of 7:30 and 10:15 AM, vehicles are required to purchase a window sticker which costs $1.75 per day or $35.00 a month. The restriction applied only to automobiles at first, but subsequently was applied to taxis as well. Simultaneously, monthly parking charges were increased by $8.80 to about $30.00. Altogether this amounted to an incremental day use fee of about $2.00.

As hoped, the result was a 73% decrease in vehicles entering during the rush hour. In the half-hour from 7:00 to 7:30 there was a 23% increase. Car-pools, which have long been encouraged by the government, increased by 60%. Approximately 35% of car-commuters shifted to bus, 15% shifted to an earlier entry, and 30% shifted to car-pools.

Speeds in the central area increased by about 10% on the inbound radial arteries and by about 20% within the restricted area, while decreasing by about 20% on the ring road.

As might be expected, through trips dropped considerably, and conditions for pedestrians were significantly improved. A public opinion survey revealed that all classes of travellers except car-owners considered themselves to be better off, and even motorists believed that the effect on the city was favorable.

Two surprises were encountered. The first of these was that there was virtually no change in the evening rush traffic (not restricted) even though there were now significantly fewer car commuters. The second surprise concerned the park-and-ride and free shuttle bus facilities which had been provided on the ring road. This service attracted very few patrons.

Analyses indicate that in terms of time savings, the traffic restraint scheme yielded a rate-of-return of at least 15%. This, however, was not the main objective. Traffic conditions in Singapore were by no means badly congested before the experiment. Rather it was the general objective of changing people's attitudes toward the use of cars for commuting that motivated the planners of the Area License Scheme. The aim was to prevent the existing moderate congestion from growing progressively worse. To solve the problem, the planners perceived that they had to, first, explain the rationale behind the need for more widespread use of public transport and other high occupancy vehicles, and second, induce motorists to review and fundamentally change their attitudes towards the ownership and use of cars. This revision of motorists' attitudes and, hence, behavior was expected both to reduce the problems caused by congestion and at the same time create an environment in which public transport could be improved.

Bangkok Traffic Management

Traffic in Bangkok is extremely congested. Average trip speeds on the main arterials are frequently as low as 5 kph and

seldom above 15 kph during peak hours. For 75% of the day, routes operate at close to capacity. In 1977 the Thai government set up the Bangkok Traffic Management Project (See [8] for a detailed description) with the purpose of achieving the following objectives:

- Strengthen urban traffic management by organization of a central traffic planning office, reorganization of the traffic police, and improvement of their equipment.
- Increase capacity of the urban road network via the improvement of signalization, the construction of flyovers, and other traffic engineering improvements.
- Improve public transport via bus priority measures, especially bus lanes and bus loading bays, and by staggering work and school hours.
- Discourage low-occupancy vehicle use via parking controls and by the introduction of a road pricing scheme for the central area.

Unfortunately, virtually none of these goals has been achieved to date. The key element in the program was an area permit system similar to that in Singapore, except that it would extend from 6:30 AM to 6:00 PM. In Bangkok there are at least 13 different agencies involved in transport planning, operations and implementation falling under two separate ministries. An office was established to attempt to achieve coordination. However, even though the area pricing scheme had been agreed to "in principle" in the establishment of the project, opposition was so strong that the office did not meet, and no authoritative approval was obtained for any of the project's programs. It was not until the abandonment of the road pricing project that any of the projects could proceed. Even so, as of March 1980, little actual progress had been achieved, mainly due to problems in coordination and in obtaining technically qualified staff.

Why was the Singapore project so much more successful than the Bangkok project? It is tempting to say that the failure in Bangkok was due to political problems, and that such a program can only be successful if it has the full support of the top

level in the government. However, it must also be recognized that the physical problems in Bangkok are an order of magnitude greater than those in Singapore. Illustrative of the problems in implementing a proposed 100 kilometers of bus priority lanes are the following (quoted from [8]):

- The traffic law did not permit the introduction of with-flow bus lanes until it was amended some 10 months after commencement of the Project.

- Bus flows are often in excess of 200 per hour on major roads and sometimes in excess of 400. When it is considered that all buses stop at all stops and that there is only a limited possibility of constructing adequate bus bays, staggering bus stops by route or introducing double-width bus lanes, the capacity of the proposed bus lanes is seriously in doubt. Indeed it is a real possibility that such measures would result in "car-priority" not bus-priority.

- There are few interconnecting links between minor roads in Bangkok and consequently it is difficult to restrict turning movements at the frequent connections between minor roads and the major road network.

- With the predominance of shop house type developments, such frontage activity as loading and unloading is a feature of the main road network, hence parking and/or unloading must be permitted at some time.

- There are several grossly oversaturated junctions with no available bypass route. Consequently, there is a real risk of extending queues back through upstream junctions if capacity for private vehicles is reduced.

- Follow-up procedures for traffic law offenders is poor, and unless offenders are stopped and fined "on the spot," it is unlikely that they will be dissuaded from making future contraventions of the regulations. Enforcement of bus lane regulations could therefore be difficult and itself reduce capacity.

- The edge of the carriageway drainage channel is often deep and wide as a result of frequent road resurfacing activity. The nearside lane is therefore reduced in capacity and a bus lane may well have to be 4 m in width - a dimension which cannot usually be afforded in Bangkok.

- Almost continuous, uncoordinated roadworks or excavations have rendered the introduction of with-flow bus lanes impossible on many major routes over the last 18 months.

Clearly in such an environment, a bus-priority lane project is not a simple problem in traffic management, but will require extensive road reconstruction and coordination among a large number of agencies.

Curitiba Transport System

One of the world's outstandingly successful transport systems has been installed in Curitiba, Brazil [2], a city of almost 1,000,000. It is based on a system of three radial "spines" which come together to spiral the city's center. Each spine consists of three parallel roads. The center road carries a high speed busway, on either side of which are lanes for local access to shops. The two outer roads form a pair of four-lane one-way avenues for automobile traffic to and from the center. However they are deflected from the center itself, where 30% of the streets are reserved for pedestrian use. In the center, a computer system controls 200 traffic signals. Extensive control of parking is enforced in the center to discourage long-term parkers.

Two types of bus service are in operation. Express buses travel down the spine busways at fairly high speeds, while local buses provide a collector/feeder function. Conventional buses operate in the areas not serviced by the spines.

Thus, the Curitiba system is an adaptation of the linear city concept, oriented to high density corridors with a high speed mass transit system. According to the World Bank [2], "the high capacity transport corridors and linear axes development policy have done much to prevent central area traffic congestion while virtually eliminating congestion elsewhere. Congestion has also been avoided through the introduction of extensive and well-planned traffic management schemes in the city center."

Current Urban Transport Projects

A number of urban transport programs, which include many of the measures discussed in this report, are currently underway with financing from the World Bank [2]. These are listed in Exhibit III-2.

EXHIBIT III-2

ELEMENTS OF CURRENT URBAN TRANSPORT PROJECTS

	Abidjan	Bangkok	Bombay	Calcutta	Kuala Lumpur	Madras	Nairobi	Recife	San Jose	São Salvador	Teheran	Tunis
Low Cost Pavement								X		X		
Road Widening		X			X				X			
Flyovers		X			X							
Ring Routes								X				
TOPICS	X	X	X	X				X	X	X	X	X
Area Traffic Control	X	X							X			X
One-Way Streets											X	X
Cycle Paths					X							
Foot Paths	X						X					
Pedestrian Crossings	X				X							
Busways	X											
Bus Lanes	X	X			X		X	X	X	X		X
Bus Terminals	X		X	X								
Standard Buses			X	X		X					X	
Express Buses	X											
Area-Use Pricing		X			X				X			
Park-and-Ride Shuttles		X								X		
Parking Controls		X			X			X		X		
Pedestrian Streets/Malls		X						X				
Staggered Hours		X										

LIST OF FOOTNOTES

1. United Nations, Concise Report on the World Population Situation in 1970-1975 and its Long-range Implications, July 1974, Sales No. E.74.XIII.4. Urban data are based on national definitions. In this context, "South Asia" includes the Indian subcontinent, Indonesia, Malaysia, the Philippines and Thailand.

2. Gerald Leach, "The Motor Car and National Resources," Working Paper No. 4, Organization for Economic Cooperation and Development, Paris, 1972.

3. Two such planning studies are the urban transport plan for Suva, Fiju, conducted in 1973-74 by Freeman Fox and funded by the UK Ministry of Overseas Development and the transport plan for Quito, Ecuador, conducted by Louis Berger in 1973 and funded by U.S. AID.

4. World Bank, Urban Transport, Annex 5, Table 5:1, pp. 74-75.

5. The fraction of income allocated to transportation rises to about 5% then may jump to 10% with the purchase of a car (6).

6. Current costs are approximately four times these values due to inflation and higher interest rates.

7. Data from The Kenya Road Transport Cost Study, RRL Laboratory Report 672. Although these cost curves were developed for rural roads, the shapes correspond closely to data from other urban sources.

8. While the value of employment is not being addressed in this report, the replacement of private transport firms by a municipal bus company is not likely to create more jobs than it removes.

9. For an excellent discussion, see Annex 7 of the World Bank's Sector Policy Paper "Urban Transport."

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IV. ENERGY AND ELECTRIC POWER SYSTEMS*

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IV. ENERGY AND ELECTRIC POWER SYSTEMS

INTRODUCTION

The economic well-being and standard of living in lesser developed countries (LDCs) are directly linked to the cost and availability of fuel and electricity to meet domestic needs. Also of critical importance is the reliability of the energy supply, that is the ability of an energy producer (such as a utility) to meet the demand of the user at the time of need. Many LDCs are faced with an inadequate conventional fuel supply and a lack of a reliable distribution system for the end product, be it fuel, electric power, or both.

For those LDCs which lack reserves of conventional oil and gas, their fuel needs may be met by the importation or, alternatively, through the development and use of such non-conventional resources as biomass, wind, and small hydro. The development and use of indigenous, non-conventional resources consequently circumvent the need for out-of-country capital outlays for foreign fuel. Capital is then available to develop domestic fuel reserves and to stimulate domestic industry, the latter having been established in part to produce, transport, distribute, and convert the indigenous fuel resources to needed forms of energy.

Many oil importing and oil exporting LDCs suffer from inefficient and unreliable electric power generation, transmission, and distribution systems. The inefficiency and unreliability extend to the end-user because of unreliable electrical supply, and because electrically-driven equipment is in many cases antiquated, in poor repair, and seldom subject to any type of control to maintain efficient operation and performance. The cumulative result is a drain on the utility because it must provide capacity in excess of what would be required by well-managed electro-mechanical equipment. Properly designed and maintained power systems provide reliable electric service and thereby serve to stimulate industrial growth and domestic employment.

In 1976, developing countries consumed 12 percent of the world primary energy and were responsible for 15 percent of world petroleum consumption. As these countries develop and become industrialized, their energy demand will grow and consequently their supply of fuel, either imported, indigenous, or both, will have to be augmented. The trend in energy demand for developing countries can be gleaned by examining their consumption during the period 1970 - 1975. During this period, the average energy consumption for developing countries rose at a rate of approximately 6 percent annually, while the corresponding rate for industrialized countries, discounting the downturn during 1973 and 1974, was approximately 4 percent. Projections for the next decade (1980-1990) place the annual rate of growth in energy consumption by developing countries at approximately 6.2 percent [1].

In light of the severity of the energy supply and demand situation faced by the developing countries, a critical need exists for a well-conceived plan of energy management at both the national and sub-national levels. The state-of-the-art (SOTA) review addresses this need and offers strategies for meeting the existing problems and those that lie ahead. The SOTA review examines the sources of energy, energy consumption, and electric power supply in developing countries as background for the development and definition of practical strategies to meet the problems in energy management. The strategies have been broken into a number of areas and are described in detail in the concluding section.

SOURCES OF ENERGY IN DEVELOPING COUNTRIES

For the purpose of the SOTA review, sources of energy for LDCs have been categorized as conventional or non-conventional. The conventional sources of energy in the industrialized world are oil, natural gas, coal, and hydro, and are termed commercial sources. On the one hand, certain indigenous fuels (such as firewood, crop residues and animal dung), which may be considered conventional fuels for LDCs since these fuels supply 50 to 90

percent of their domestic energy needs [2], are termed non-commercial. The reason is that their collection and use seldom are supported by a formal infrastructure of commerce among or within countries.

The production and consumption of fuel resources by developing countries are shown in Exhibit IV-1 for 1980 and 1990. The deficit between oil production and consumption for the oil importing developing countries (OIDCs) is approximately three times the domestic rate of production for both years, as is indicated by the data in Exhibit IV-1.

The chief sources of energy in developing countries are oil, natural gas, coal, and hydro, with oil being the most prominent. In 1980 nuclear energy and other sources, primarily non-conventional, cumulatively represented less than 2 percent of the production of domestic energy resources of developing countries taken as a whole, and less than 6 percent for OIDCs. The projected contribution of nuclear and other sources to the energy requirements of developing countries in 1990 for the developing countries taken as a whole and OIDCs is approximately 9 percent and 17 percent, respectively, as may be discerned from the data in Exhibit IV-1.

Oil

For the past thirty years, oil has been the world's primary source of commercial fuel and will continue to supply 30 to 40 percent of the world's commercial energy demand over the next ten years, in spite of world efforts to develop alternative fuel sources. In the case of developing countries, the World Bank estimates that oil will supply a much higher share of the demand for commercial energy [1]. The lack of substantial new discoveries of world reserves of oil is seriously affecting the capability of the world petroleum supply to meet the demand of

EXHIBIT IV-1

PRODUCTION AND CONSUMPTION OF FUEL RESOURCES FOR DEVELOPING COUNTRIES

	1980								Projected 1990							
	LDCs				OIDCs				LDCs				OIDCs			
	Produced (Mboe)	(%)	Consumed (Mboe)	(%)	Produced (Mboe)	(%)	Consumed (Mboe)	(%)	Produced (Mboe)	(%)	Consumed (Mboe)	(%)	Produced (Mboe)	(%)	Consumed (Mboe)	(%)
Oil	13.2	62.9	9.2	55.0	2.0	25.6	6.5	52.4	19.4	54.6	15.4	50.4	3.6	23.7	11.4	50.0
Gas	3.0	14.3	2.1	12.6	1.5	19.2	1.4	11.3	5.2	14.6	3.0	9.8	2.6	17.1	2.6	11.4
Coal	2.5	11.9	2.6	15.6	2.4	30.8	2.5	20.2	3.7	10.4	3.8	12.4	3.3	21.6	3.4	14.9
Hydro	1.9	9.0	1.9	11.4	1.5	19.2	1.5	12.1	4.1	11.6	4.1	13.4	3.2	21.1	3.2	14.0
Nuclear	0.1	0.5	[illegible]	0.6	0.1	0.3	0.1	0.8	1.2	3.4	1.2	3.9	1.0	6.6	1.0	4.4
Other	0.3	1.4	0.8	4.8	0.3	3.9	0.4	3.2	1.9	5.4	3.1	10.1	1.5	9.9	1.2	5.3
Total	21.0	100.0	16.7	100.0	7.8	100.0	12.4	100.0	35.5	100.0	30.6	100.0	15.2	100.0	22.8	100.0

Notes:

1. "Other" includes alcohol, other non-conventional primary energy sources, unallocated energy, and exports of gas.
2. Data taken from reference 1.
3. Mboe = million barrels per day of oil equivalent.
4. The Philippines is classified as an OIDC.

the industrialized world and the growing demand of the developing countries. Although some of the oil importing developing countries are becoming oil producers (e.g., Barbados, Brazil, Chile, Colombia, Ghana, Guatemala, India, Ivory Coast, Morocco, Pakistan, Philippines, Thailand, Turkey, and Yugoslavia), and may substantially reduce their dependence on imports in the next years, the opportunities for the other oil importing developing countries are limited due to a lack of large, easily recoverable reserves. The economic feasibility of further oil exploration and development of smaller oil deposits requires examination in light of the potential development of alternative sources of fuel.

In 1978 approximately one-quarter of the developing countries were net exporters of oil. However, due to the fact that several of these oil exporting countries have large populations which can absorb significant amounts of their surplus during the next ten years, the percentage of oil exporting countries may drop unless new oil deposits are discovered or alternative means of energy are developed to meet the increased demand.

The remaining three-quarters of the developing countries require imported oil to meet their energy needs. According to World Bank estimates, some countries (e.g., Chad, Ghana, Ivory Coast, and Pakistan) are projected to have the capability of becoming self-sufficient within the next ten years, while others (e.g., Brazil, Republic of Korea, and Turkey) may become increasingly dependent on oil imports due to growing demand unless alternative sources are developed [1].

Natural Gas

In many instances, natural gas has proven competitive with or has displaced oil as an energy source. Natural gas is often used to supply the requirements of large, stationary energy consumers, such as power plants and steel mills. Due to low energy density, on an uncompressed volume basis, natural gas is not normally used to power mobile energy users, such as vehicles and aircraft. Fuel oil, or its derivatives, generally are used to meet the

needs of mobile sources. In terms of production, natural gas represents approximately 14 percent of the total production of developing countries taken as a whole.

Due to low volumetric energy density of natural gas, its transportation and storage have proven to be a disadvantage in comparison with oil. For developing countries, which depend in many instances upon fuel supplies delivered by ship, the low volumetric energy density of natual gas has been an impediment to its importation. The advent of technology during the 1970's for producing, transporting, and storing liquified natural gas (LNG) may increase the use of natural gas during the next ten years, provided sufficient natural gas reserves are available to meet the world wide demand.

The natural gas reserves of developing countries have not been exploited significantly primarily due to the lack of a sufficient market for the fuel to justify its extraction, treatment, and transmission and due to the competitive advantage of domestically produced or imported oil. Typically, economic development of domestic gas reserves and the associated transmission and distribution system require a large energy demand (e.g., large process heat requirements by industry or power generation). According to the World Bank, several countries are in such a position, including Pakistan, Argentina, Colombia, Algeria, Bangladesh, and Romania [1].

Coal

The depletion of known oil and gas reserves and an ever increasing demand for energy have stimulated a renewed use of coal, despite potentially serious environmental problems (e.g., production of carbon dioxide [CO_2] and sulfur oxides) and the requisite switching of an oil-based utilization technology to one that is coal based. The motivation for considering the use of coal is derived from the existence of economically recoverable reserves, nearly five times those of oil, and from the fact that the technology for its extraction, handling, and thermal conversion has been previously established. In addition, coal is well

suited to particular uses, namely power generation and steel production.

Approximately one-quarter of the developing countries exploit their domestic coal deposits. However, the majority of coal production occurs in one-third of the coal producing LDCs, the primary producers being Brazil, Colombia, India, Republic of Korea, Mexico, Romania, Turkey, Vietnam, and Yugoslavia [1].

Coal production among the developing countries amounts to approximately 6 percent of world production, and during the period 1973-78, the average annual rate of growth in production among LDCs was approximately 4.5 percent per year. Present estimates of the rate of growth of coal production among LDCs extend from negative growth, as a consequence of environmental pressures and development of non-conventional sources of fuels, to 7 percent if concerted efforts are taken to increase production. In the latter case, the majority of the growth would most probably occur in those LDCs that already have a substantial coal producing industry.

Besides direct combustion for energy production, coal may be converted directly to an intermediate energy source, termed synthetic fuel (synfuel), that may be gaseous or liquid. Medium grade synthetic gas (syngas) and synthetic natural gas (SNG) are two gaseous forms producible by conventional technology. Similarly, synthetic liquid fuels may be produced from coal. The impetus for coal conversion to the various forms of synfuel stems in many cases from a desire to maintain the handling characteristics of a gaseous or liquid fuel and from the desire to exploit the potential of using an available fuel, coal, as a source of energy.

Uranium

Uranium-to-fuel nuclear power generating facilities are widely distributed throughout the world, and forecasts indicate that neither uranium supply nor enrichment capacity are expected to constrain nuclear growth [3]. One projection [3] places

uranium as the fastest growing major energy source over the next two decades with its share of the world energy supply growing to 10 percent by the year 2000. However, other projections [2] indicate that nuclear growth will be curtailed due to a combination of higher nuclear plant costs, longer than anticipated construction times, lower than estimated growth in electrical demand, and political problems concerning nuclear and reprocessing hazards. Although uranium deposits may be found in developing countries, few have the capability for processing the raw material into fuel rods or have sufficient demand for electric generating capacity for a conventional-sized nuclear power plant (i.e., greater than 500 MW).

Uranium production in 1980 amounted to 0.5 percent of the total fuel production in developing countries taken as a whole and 1.3 percent in OIDCs. The World Bank projects the production in 1990 to be 3.4 percent and 6.6 percent, respectively, for developing countries and OIDCs.

Large Hydroelectric Generation Systems

Countries have long taken advantage of water as an energy resource, particularly those countries that have an abundant supply of water and a typology conducive to water storage and containing a sufficient hydraulic drop. Besides power generation, hydro development oftentimes serves as a means of flood control and as a means of storing irrigation water. Conventional hydroelectric facilities typically have rated capacities in the range of 100 MW to 10,000 MW.

The development of conventional hydropower sources in developing countries has been restrained by the high capital costs that are required for water impoundment (i.e., construction of reservoirs and dams) and for the generating station. In addition, relatively few LDCs possess the demand for electric power which would justify the cost of a conventionally sized hydroelectric generating facility. Also compounding the lack of hydropower development is the lack of a domestic industry to design,

site, and construct a hydro plant given the need for a historical data base for the catchment region and a thorough understanding of the geology of potential dam sites.

Oil Shale

Oil shale, consisting of hydrocarbons bound in rock (e.g., shales or other rock), is undergoing scrutiny as a hitherto marginal energy source whose economic development is becoming more feasible as the price of oil continues to increase. Oil shale may be processed using size reduction and heating to recover the oil for use, or it may be burned directly as a low-grade fuel. The latter case requires combustion units specifically designed for that because the ash content of the fuel is typically in the range of 70 to 90 percent. Yields of oil shale deposits are typically in the range of 10 to 40 U.S. gallons-per-ton of shale.

Large, known reserves of oil shale (exceeding one trillion barrels of oil for shales yielding more than ten gallon-per-ton) exist in countries within Africa, Asia, and South America. Unproven reserves exist in a number of LDCs, including Zaire, Burma, Morocco, Brazil, Thailand, and Turkey.

Tar Sands

Large, proven reserves of tar sands, i.e., rock containing heavy, viscous oil, exist in Canada and Venezuela. Other large, unexploited deposits are known to exist in the USA, USSR, Romania, Albania, Syria, Ivory Coast, Ghana, Malogasy, Trinidad, Ecuador, and Peru. The World Bank estimates that known reserves of tar sands contain in excess of 1.5 million barrels of oil [4].

Tar sands typically contain 10 to 20 percent oil by weight. The oil may be recovered through surface mining and hot water or solvent refining methods, or alternately, with the use of recovery wells, complemented by steam injection.

Peat

Peat, a decayed fibrous organic material, may serve as a low-grade fuel. It typically composes the soil of marshy areas and consequently is high in moisture content. To be used, peat must be dried to 30 percent moisture or less, at which point its heating value approaches that of wood. Due to its fibrous matrix, peat when dried is a low density fuel, and as such it exhibits a low energy density on a volumetric basis. Dessication may be used to make the fuel more amenable for transporation and materials handling.

Presently, peat is not widely used in LDCs. However, peat reserves are known to exist in several LDCs, including Belize, Cuba, Jamaica, Chile, Rwanda, and Burundi.

Biomass

Biomass, defined as organic materials that may be rejuvenated over a relatively short time span (i.e., several years) when compared to that required for fossil fuels, has long served as an indigeneous fuel source. Within the general definition of biomass are included timber, wood waste, charcoal, crop waste, the organic portion of solid waste (e.g., methane gas), and manure.

Biomass resources, mainly in the form of firewood, charcoal, crop residues, and manure, are used widely in developing countries. Overall, the World Bank estimates that utilization of biomass represents 20 to 25 percent of the fuel consumption in the developing world (or an equivalent of 8.5 million barrels of oil per day) [1].

Stimulation of the development of biomass resources in LDCs is advantageous due to the location of many LDCs in areas which receive high rates of solar insolation and rainfall and due to the diffuse energy demand which characterizes many LDCs.

Besides the direct combustion of biomass for energy production, it may serve as feedstock for the production of fuel liquids or gases (e.g., alcohol production through acid or enzymatic hydrolysis or combustible gases produced by gasification or anaerobic digestion).

Solar

Solar insolation has many uses as a primary source of thermal energy, both in low and high temperature applications. Solar insolation may also be used for electric power generation using photovoltaic cells. One of the chief uses of solar energy in LDCs is the drying of commodities or materials in the open air. The high rate of solar insolation experienced by many LDCs and their decentralized requirements for energy make the direct use of solar energy a highly exploitable energy form.

Wind

Wind energy harnessed by windmills and wind generators has been exploited for decentralized energy uses in those areas that have a reliable source of wind. Generally, average wind speeds in excess of 2.5 meters-per-second (m/s) are required for useful power production [5]. In addition, the constancy of the wind is an important factor. The use of wind energy is highly site-specific, i.e., dependent upon local meterological conditions and topology. Even within the same general locality, wind velocities may vary significantly. No published detailed assessment of the potential of wind energy in LDCs was found in the literature.

Geothermal

Superheated water and steam contained in underground aquifers may be used for electric power production, space heating, and industrial process heat. The water and steam are extracted using geothermal wells with the heat energy being subsequently recovered using thermal conversion equipment. The spent working fluid is subsequently discharged or re-injected into the ground. Geothermal resources have been developed and used in over half a dozen countries. According to the World Bank, the following LDCs may have exploitable geothermal resources [4]:

Mexico	Venezuela	Turkey	Yemen A.R.	Rwanda	Martinique
Guatemala	Bolivia	Iran	Ethiopia	Burundi	Guadeloupe
El Salvador	Chile	India	Kenya	St. Lucia	Solomon Is.
Nicaragua	Argentina	Indonesia	Tanzania	Dominica	
	Costa Rica	Philippines	Cameroon		

Small Hydropower Applications

The use of water for small-scaled hydroelectric power generation is also gaining renewed acceptance due to its ability to meet decentralized energy needs. The term "renewed" is used because the technology is over 200 years old [6]. Small hydro is commonly used to refer to hydroelectric generators with capacities less than 100 kw. The typical range is 5 to 50 kw.

The availability of water, the existence of an adequate hydraulic head, the requirements for water storage, and the local power demand are significant factors that impact the feasibility of developing small hydro resources.

Developing countries utilize hydro resources for crop processing and for pumping water using water wheels. These countries include Afghanistan, Nepal, and Turkey. According to the World Bank, small hydro turbine generator systems with capacities of less than 50 kw have been installed in over two dozen LDCs, and in China alone there are reportedly over 80,000 small hydroelectric generating systems [7].

CONSUMPTION OF ENERGY IN DEVELOPING COUNTRIES

The consumption patterns of LDCs were addressed briefly in the discussion of primary commercial energy resources. In particular, the dependence of OIDCs on imported oil was indicated by the data presented in Exhibit IV-1. A breakdown of the energy demand of developing countries by consuming sector shows that the industrial and transportation sectors are the primary consumers of commercial energy, accounting for 70 to 80 percent of the total. Household consumptions of energy in LDCs is typically in the range of 10 to 20 percent of total consumption. In comparison to developing countries, developed countries tend to have a greater portion of their commercial energy usage tied to the household sector, primarily due to the increased energy usage that is fostered by having the convenience of electric power in

the home. A breakdown of the end uses of commerical energy by consuming sector for selected LDCs and for the U.S. is shown in Exhibit IV-2.

Urban and Rural Households

Household consumption of energy resources in LDCs represents a significant contribution to their total energy usage. The urban sector relies heavily upon the use of non-commercial energy resources, especially such traditional fuels as firewood, charcoal, animal manure, and crop residues. The use of traditional fuels is even more dramatic in the rural sectors, where such fuels may comprise virtually all of the energy supply. According to World Bank estimates, a billion people, or approximately three-quarters of the population of developing countries, presently use traditional fuels for cooking [1]. Most households use firewood, but crop residues and animal manure are used by 0.5 to 1 billion persons. Those areas where traditional fuels contribute significantly towards meeting the total energy demand are, in descending order, Africa, Asia, and Latin America.

The primary modes of fuel consumption in the urban and rural sectors are cooking (typically 50 to 80 percent of the total consumption), water heating, lighting, and space heating. The latter (space heating) is negligible for many LDCs located in warm climates; in cooler climates, space heating may be supplied as a by-product of other uses, e.g., cooking. Data are available to indicate that the energy consumption of rural households (7.6×10^3 to 17.1×10^3 BTU per capita) is greater than that of urban households (3.8×10^3 to 6.6×10^3 BTU per capita).

The supply of firewood in many developing countries is dwindling due to rising demand and resource exploitation. Many countries face critical shortages, particularly those with a significant rural population. One measure of the critical nature of the

EXHIBIT IV-2

END USES OF COMMERCIAL ENERGY (Percent)

End Use	India[1] (1971)	Mexico[1] (1971)	Typical LDC Ranges[2] (1978)	U.S.A.[3] (1972)
Agriculture	5	1	<5	4
Industry	39	43	20-65	29
Transportation	32	39	NE[c]	35
Commerce	6	3	NE	9
Household				
Low Income			10	
Middle Income			10-20	
Average	18	14	10-20	23
Total	100	100	100	100

1. Data taken from reference 8.
2. Data taken from reference 1.
3. NE = no estimate given in the reference.

situation is the rate of deforestation being experienced in LDCs, which is 1.3 percent per annum according to the World Bank [1].

Industry

Within LDCs the consumption of energy by the industrial sector depends to a significant degree upon the specific types of industries in the area, in particular the presence or absence of such energy-intensive industries as steel, cement, refined petroleum products, chemicals, pulp and paper, aluminum, and ammonia. Consequently, industries in LDCs may utilize anywhere from 20 to 65 percent of total commercial energy consumed. The average, however, tends to be in the range of 35 percent [1]. In OIDCs the primary fuel for meeting the demands of industry is imported oil.

Since industry occupies a significant position with respect to energy usage, it is a prime area for energy conservation attempts through process changes to reduce unit energy consumption and through improvements in the thermal efficiency of industrial equipment. In addition, for OIDCs, the development of indigenous energy resources also represents a means of displacing some of the imported oil supply.

Transportation

Within LDCs the transportation sector consumes 20 to 40 percent of the commerical energy supply, with the low income LDCs being at the lower end of the scale. The primary consumption sub-categories are road transport, accounting for 70 to 85 percent of the energy consumed in the transportation sector; rail transport, 3 to 5 percent; and air transport, 5 to 10 percent.

Virtually all of the energy needs of the transportation sector are met by petroluem-based products. Consequently, for OIDCs in particular the energy requirements for transportations can cause serious economic dislocations. Some LDCs (e.g., Brazil) have countered the rising energy demand in the transportation sector with the development of such indigenous energy resources as alcohol derived from biomass.

Agriculture

Consumption of energy by agriculture comprises less than 5 percent of the commercial energy resources of most LDCs. Uses of energy in agriculture include irrigation, powering vehicles, and crop processing. Due to a significant lack of data for the agricultural sector, breakdowns and an assessment of commercial as well as non-commercial energy usage are not possible.

ELECTRIC POWER SUPPLY

The demand for electric power in LDCs has grown at an average rate of approximately 8 percent over the past half dozen years. The growth in demand during the 1980's is estimated to be slightly higher, i.e, in the range of 8 to 9 percent [1]. Despite the relatively constant rate of growth in electricity demand, it is of significance that electric power consumption is projected by the World Bank to increase from 25 percent of total commercial energy consumption in 1980 to 31 percent by 1990. Hence, use of electric power will increase substantially over the next decade and displace some non-electric energy consumption in the consuming sectors, e.g., electric lighting may be used in place of lights fueled by petroleum products.

Power generation in LDCs is provided primarily by oil, natural gas, coal, and hydro. Oil and hydro are the chief contributors to electric power generation, supplying approximately 30 and 40 percent of total generating capacity, respectively. Over the next decade, the World Bank estimates that the overall contribution of oil to the total generating capacity of LDCs will be diminished. The primary energy resources which will replace oil will be natural gas (whose use is projected to grow 14 percent per annum), coal (10 percent per annum), nuclear (30 percent per annum), and geothermal (25 percent per annum).

The type of system chosen for power generation depends to a great degree on the characteristics of the load, the present and projected demand for electric power, and the availability of a reliable fuel supply. The characteristics of the load (i.e.,

magnitude and transient nature) narrow the choice of systems. For example, steam and nuclear generating facilities are used to provide base-load requirements, and diesel generators are used for peaking or small base-load requirements.

System selection is also affected by cost. For example, hydro, geothermal, and nuclear generating facilities have high capital costs, 50 to 80 percent higher than generating facilities fired by oil or natural gas. However, the operating costs are generally less due to the relatively low cost of the fuels (water, geothermal steam, and uranium, respectively). The capital cost of coal-fired generating facilities is typically 20 percent higher than that for oil- or gas-fired systems. In OIDCs, the growing demand for electric generating capacity and the high cost of imported oil have resulted in the use of generating facilities fueled by domestic resources (such as coal, geothermal steam, and water). In addition, the exploitation of biomass resources to fuel electric generating stations is also being evaluated. Small hydro generating systems and wind driven electric generation also are being evaluated. Small hydro generating systems and wind driven electric generation also are being evaluated for meeting power demand. These methods of power generation are particularly suited to the decentralized needs of rural areas.

The transmission, distribution, and end use of electric power in LDCs require scrutiny since cumulatively they influence the demand for generating capacity by way of energy losses throughout the system. In LDCs losses not only occur at the generating facility, where on average 72 percent is rejected as heat and 1 to 6 percent of the generated power is used in-house, but significant losses (typically 10 to 25 percent) also occur in transmission and distribution systems. The latter losses are approximately twice those of efficient systems.

The end-users of electricity also affect generating capacity both through their demand for power and through any excessive inefficiencies in energy conversion because inefficient,

electrically-driven equipment requires generating facilities with larger than needed generating capacities. Consequently, the use of efficient electrically-driven equipment in the future can have a significant bearing on reducing future generating capacity. In addition, energy conservation measures installed or practiced at the present time will allow existing generating capacity to extend into the future.

STRATEGIES FOR ENERGY MANAGEMENT

In this section, strategies are proposed for the purpose of satisfying the existing and future energy needs of developing countries and their respective urban and rural subdivisions. The strategies have been formulated in light of the circumstances that are particular to developing countries. Key facts that influence the choice of strategies are:

(1) In many developing countries a wide dichotomy exists between urban and rural areas in terms of energy supply and demand.

(2) Per capita energy usage levels in developing countries are low and in many cases dispersed, thus centralized energy systems may not form the best solution for supplying energy needs.

(3) Many areas are not serviced by commercial forms of energy, particularly the rural sectors.

(4) In many developing countries, the opportunity exists for developing non-conventional and renewable resources for energy production, thereby freeing these countries from a dependence upon oil-based energy supplies and energy conversion technologies.

(5) Electric power demand in developing countries will grow significantly during the next decade.

(6) Developing countries may have highly developed, energy intensive mineral industries while at the same time lacking industrialization in the rural sector.

(7) Labor in developing countries is abundant and economical, while at the same time capital is scarce.

(8) Transmission and distribution systems for fuel supplies and electricity are frequently non-existent and seldom are well developed.

Due to these circumstances, solutions to the energy problems in developing countries may not necessarily follow the pathways established by the developed countries because such solutions are in many cases energy- and capital-intensive. In addition, the dispersed nature of much of the energy demand in LDCs is amenable to the development of non-conventional energy resources (such as biomass, geothermal, and small hydropower). Such non-conventional resources are available domestically to many developing countries.

Also to be considered in the selection of a particular strategy is the position of a developing country in terms of the balance between its energy demand and its domestic energy supply, that is, whether the country is a net importer of energy, net exporter, or energy balanced. While many of the proposed strategies are aimed towards reducing energy usage and are therefore applicable to all developing countries, several strategies (e.g., the use of non-conventional as a replacement for imported fuels) are aimed specifically towards the energy importing countries and those seeking to remain energy balanced.

Energy Conservation

Since energy conservation can form one of the most economical methods of tempering the demand of energy, its use cannot be overlooked. Energy conservation consists of minimizing the loss of energy in a system and of using less energy for a particular purpose or task while at the same time maintaining the original quality. The reduction of losses can range from increasing the overall efficiency of energy conversion in industry by modifying a piece of original equipment (e.g., a turbine generator to increase its thermal efficiency) to reducing the fuel needs of a rural household through the use of energy efficient stoves. The majority of conservation measures that may be instigated in the household and industrial sectors typically are labor intensive,

require relatively little capital expense, produce significant reductions in energy use, and have short payback periods.

Industry

Existing businesses should conduct energy audits (surveys) to identify the sources of energy losses and their magnitudes. Areas requiring scrutiny include the productive use of waste heat, plant downtime, plant illumination, preventative maintenance programs, and modifications to existing processing equipment to increase its energy efficiency.

Future industrial development should consider the specification and use of energy efficient equipment (electric motors, air conditioners, etc.), the use of indigenous energy supplies, and, for versatility, the use of energy conversion equipment capable of burning multiple fuels, solid, liquid, or both. The use of cogeneration may also be advantageous in certain situations. The World Bank estimates the industrial sector of LDCs could reduce its energy consumption at present production levels between 5 and 25 percent through various conservation measures [1].

Transportation

Conservation may be practiced in the transportation sector by using high density carriers where practical, such as buses for intra-city travel, and through the use of energy efficient vehicles, such as diesel-powered autos and trucks. Energy savings of up to 20 percent may be realized in the transportation sector through shifts to energy efficient vehicles.

Electric Power

Electric power systems in LDCs present a number of opportunities to practice energy conserving measures, one of the chief areas being the efficiency of thermal conversion units and transmission and distribution systems. The low power plant efficiency suffered by many generating facilities in LDCs is a general consequence of their relatively small size. Linking the demand sectors, for example by interconnecting regional grids where possible, would serve to increase the design capacity of the

power plants and concomitantly the thermal efficiency of conversion. The increases in efficiency, and therefore power production from a given input of fuel, could be expected to be in the range of 7 to 25 percent.

Additional losses that occur in the electric power systems of developing countries are a consequence of inefficient transmission and distribution networks. The additional losses may be twice those experienced for comparable systems in developed countries. Much of the improvement in transmission and distribution efficiency could come in the form of proper system design, including the selection of correct sizes for conductors and the selection of efficient switching equipment.

Household

The extensive use of firewood in households, and its manner of conversion to heat, particularly in rural areas, represents a significant potential for energy conservation through improving stone design and operating procedures. Due to the sheer number of households presently using firewood in the most rudimentary of burning chambers, conservation efforts on even a modest scale would significantly contribute towards an easing of the present drain on the forests of developing countries. The use of energy efficient stoves could result in energy savings between 40 and 80 percent over the present practice of cooking over open fires. The overall energy savings, as a percentage of total energy consumption by the household sector, is estimated to be in the range of 5 to 20 percent.

The introduction of new stoves or unfamiliar operating procedures must be accompanied by a concerted public education program in order to gain wide acceptance. Previous efforts at introducing such energy conserving technologies have met with limited success due to the failure of the populace to adapt to unfamiliar equipment and cooling practices [9].

Also to be stressed is the notion that, at least in the case of OIDCs, the energy efficient stoves should burn indigenous

fuels, such as firewood, charcoal, domestic coal, etc., and not be designed for imported oil-based products.

Generally, the lack of use of energy conserving measures is fostered by a lack of awareness concerning the techniques that are required and their means of implementation. Consequently, public awareness needs to be heightened along with providing technical assistance at both the household and industrial levels.

Development and Use of Renewable Resources

The geographical location of many developing countries lends them to the use of indigenous renewable resources. These resources include: (1) biomass in the form of the organic components of solid waste, crop residues, animal manures, and wood; (2) direct use of (passive) solar energy; (3) hydropower resources; and (4) wind resources. The development of renewable resources is especially of interest to oil importing and energy balanced LDCs since it would lessen their dependence on imported energy supplies.

The development of renewable energy resources requires in many cases the use of non-conventional energy conversion technologies, such as biogasification and pyrolysis units for production of combustible gas and boilers specific to a particular type of feedstock, e.g., bagasse. Consequently, these technologies need to be evaluated, and if appropriate, implemented. Of particular importance to the implementation of alternative energy strategies are an evaluation of the economies of scale for the energy conversion technologies and an assessment of the market potential for the end-products. Technical assistance is required for both evaluation and implementation. Public education is also required to alert users that renewable fuel resources may be used to supply existing energy conversion systems, if such systems are modified to accommodate the new fuel. For example, modifying existing oil and gas burners to burn medium grade gas allows the gas from the biogasification or pyrolysis to be used in the existing system.

Demonstration projects would serve to increase public awareness of viable alternative energy strategies. Some projects may require government financing or loans to advance the technologies past the stages of research and development. Others, such as implementation of existing solar technology in rural areas using local materials, are relatively low cost and labor intensive. In such cases, technical assistance and training are the key ingredients to stimulate implementation.

Energy Pricing

In many ways energy pricing serves as the driving force behind energy usage. Insofar as the selection of fuel is concerned, pricing has a direct bearing on which fuels will be chosen for consideration to meet a specific energy need. Due to its importance, the energy pricing policy must be structured to reflect the true marginal cost of the fuel supply. The true cost should include allowances for exploration and development, thereby reducing the risk of severe dislocations upon depletion of a previously reliable supply. In addition, true costs must represent unsubsidized costs. For example, preferential pricing for particular consuming sectors should be avoided because it may stimulate the waste of energy at the expense of those subsidizing the cost. Also to be avoided are quantity discounts (i.e., the practice of charging lower rates for higher consumption levels) which similarly do not reflect the true cost of supplying energy. Similarly, the practice in some net energy exporting LDCs of pricing domestic energy at levels below the true cost of the supply while subsidizing the lower costs through artificially high prices placed upon exported fuels [4] requires modification in order to eliminate further potential worldwide dislocations in energy supplies.

In the case of electric power pricing policies, they should reflect the true costs of generation, transmission, and distribution. As a consequence, efficient use of electric power will be fostered. The true cost of electric power must reflect both

the costs of base-load and peak-load capabilities. For example, those users who have high peak-load requirements should carry their share of the cost burden because peaking power generating capacity is more costly than base-load capacity. Proper structuring of utility rates to reflect the difference in cost between peak- and base-load generating capacity (e.g., a time-of-day rate structure) also serves to shift peak-load users to off-peak hours, thereby decreasing requirements for peak-load generating capability and concomitantly the overall cost of electrictity generation.

Also neglected at times in the utility rate structures are increased costs due to the poor power factors of the user's electrically driven equipment. A poor power factor increases the costs to the utility because for a given amount of real power more current must be transmitted. Consequently, the generating equipment and the transmission and distribution equipment must be designed with capacity over what is needed for systems with higher power factor ratings. In general, users with power factors less than 0.85 should be penalized by the utility.

Electric Power Load Management

Load management must be practiced at new facilities having large, electrically driven systems in order to minimize their impact upon the utility grid. The use of electrical equipment during off-peak hours (especially equipment having a high peak-power demand) should be stimulated through electric power pricing policies that reflect the incremental cost of providing peaking power. In addition, pricing policies to stimulate power factor correction will serve to increase the ability of the utility to reliably meet its customers' demand. The increased reliability will result from operating the generating, transmission, and distribution systems near their steady-state design conditions, thus avoiding transient loads which cause overburdening of the utility's equipment.

Public Education and Technical Assistance

There exists a critical need to inform the populace of developing countries of all aspects of the energy situation, including supply, utilization, and conservation measures, in order to heighten its awareness and appreciation of the benefits of efficient energy utilization. Due to the dispersed energy demand in most developing countries, the educational programs must cover the urban and rural sectors as well as industry. In the case of urban and rural households where energy conservation opportunities are plentiful and available at low cost, and the gains are significant, technical assistance is required to stimulate acceptance of unfamiliar and non-traditional energy saving ideas as well as to supply the technical expertise to implement new energy conserving programs.

Technical assistance for the industrial and commercial consuming sectors is also needed. Again, the first area to be addressed should be conservation because of its relatively simple implementation and the significant energy and cost savings that may be realized. Public education in these sectors will play a key role in stimulating the use of energy conserving opportunities.

Energy Data Collection

The collection and processing of energy data are indispensible for adequately assessing future energy demand and therefore providing the documentation required to justify additional supplies of fuel or electric power. A record keeping protocol needs to be established, starting with the furnisher of primary energy resources and proceeding to the end-user. In addition, reporting formats need to be standardized as to categories, terminology, units, and conversion factors such that data can be easily accumulated, transferred, and utilized among different groups. Standardized data reporting consequently would aid in interpretation of the overall energy picture and significantly assist

consumers, municipalities, and countries in their energy planning.

Integral to an effective data collection system are the reliability and accuracy of the recording equipment. Consequently, equipment such as gas and electric meters must be kept operational and in good repair. Defective equipment should be replaced.

The lack of a systematic data collection and reporting system hindered the development of this chapter of the SOTA review, since data are in many cases lacking altogether and in other cases are in conflict among different sources. Well-planned energy management is virtually impossible without dependable historic records.

Implementation of a record keeping system must begin at the grass-roots level and be one aspect of the public education and technical assistance program. Primary energy suppliers and utilities are likely candidates for initiating data collection and reporting. The preparation of a standardized data reporting format should be the charge of a central agency or association which also provides summaries of the data. Ultimately, data need to be accumulated on a national level.

In order to speed the initiation and acceptance of a data collection system, it should be well designed, unencumbering, and straightforward. Data collection should proceed from the utility or primary energy supplier to regional agencies and subsequently on to the national level.

Energy Resource Management

Within the boundaries of developing countries are significant energy resources which require identification, exploration, and development. The pool of energy resources includes conventional as well as non-conventional fuels. The extent of these resources needs to be identified as well as the costs of exploration in order to establish the resource bank of the country. The resource

evaluation also needs to address the use of indigenous renewable resources, such as biomass and geothermal energy, including geographical locations, estimates of yield, meteorological conditions influencing the supply, and environmental consequences of use.

Resource inventories will require personnel disciplined in a wide variety of specialized fields, including conventional and non-conventional sources of energy, agronomy, and geotechnical sciences.

Policies of reforestation and forest management also need to be established in developing countries so that they may successfully contend with the increasing demand for fuel wood. The balance between sustained yield and fuel wood demand must be established in order to reduce the risk of deforestation and its subsequent deleterious effect upon the quality of the soil.

Improving Electric Power Supply

The unreliability of the electric power supply in many developing countries acts to reduce the overall domestic standard of living and also acts as a deterrent to the development of commerce and industry. Consequently, the reliability of the supply of electric power must be addressed and improved. The efforts at improving reliability do not have to entail capital-intensive measures. There are a number of preventative measures which are available at relatively low cost. These are outlined below:

1. Future generating capacity should be planned far in advance. Taxing utility equipment beyond its design capacity invites system malfunction due to overloads. The planning would be facilitated if a systematic data collection system were available to adequately assess future demand, as discussed previously.

2. Peak loads should be discouraged when the reserve capacity has been drawn to low-levels. True marginal cost pricing and time-of-day rate structures can serve to shift peak loads to those periods when there is adequate reserve capacity.

3. Sufficient fuel reserves and redundant supply should be planned in order to circumvent interruptions in the electric supply due to fuel supply dislocations. Alternative fuels should be evaluated as supplemental fuel supplies, e.g., fuel wood as a substitute for coal.

4. Suitable equipment inventories should be maintained for those elements prone to malfunctions.

5. Preventive maintenance of equipment and rights-of-way should be practiced, thus reducing the risk of extensive system downtime for otherwise small repair jobs. Personnel should be trained in proper maintenance procedures.

6. Adequate back-up generating capacity should be planned. Back-up measures may consist of tying into other utility grids (e.g., regional interconnections) or having redundant systems on-site.

7. The rate systems should be designed for prompt submittal of bills by the utility and prompt payment by the energy users. Service disconnection and fees for subsequent reconnection should be imposed for delinquent payment or nonpayment for electrical services. The foregoing will maintain the cash flow to the utility so that it may meet its expenses and thus maintain a reliable supply of power.

In addition to the above measures, for particular situations utilization of waste heat and cogeneration by the utility industry may prove to be worthwhile energy management tools and help in reducing the overall energy consumption of LDCs.

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V. WATER AND SEWER

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INTRODUCTION

The definition of "water supply" encompasses everything from a relatively sophisticated pumping, storage, treatment, and distribution system to a simple protected spring or well with no storage, treatment or extensive distribution system. Sanitation facilities include public sewerage, although this is not always relevant for rural areas and smaller or intermediate size cities in developing countries where pit privies, septic tanks, public latrines, cesspools, soak-away pits, and rudimentary drains for removal of water from the immediate vicinity of private residences and public standposts usually represent the appropriate technology. Sanitary facilities to protect the water supply and to improve public health are companion concerns to water supply systems.

Conventional sewerage, although the safest and most hygienic method of disposing of human wastes, remains the most expensive method and generally serves the needs of only a small percentage of the population. Experience within towns and cities in developing countries has shown that it is not possible to provide conventional sewerage systems for most of the people because of the high initial capital costs involved.

The subject of waste disposal is often linked to that of water supply and sewerage, with the assumption being that one entity deals with both activities. As Rybczynski, et.al. observed, most information classified under "water supply and waste disposal" deals primarily with water supply and rarely with waste. Until recently, information on waste disposal and reuse tended to be concerned with public health, engineering, town planning, and medicine, and ranged extensively across institutional boundaries. More awareness of and interest in waste recycling are now being exhibited and reflected in a growing body of literature.

Dimensions of the Problem

Water supply and quality are critical problems in every urban and rural area. Urban water supply systems differ from rural water supply systems in the respect that the development and use of an urban water supply system requires more technical skill and economic expertise. Presently, most countries lack the resources to manage water pollution from primary human and industrial wastes or to offset these effects by providing an adequate safe water supply. As stressed by Bradley (White, et.al.) in his classification of health hazards associated with water supplies, the quality and especially the quantity of water supply and the adequacy of sanitation determine in large measure the level of public health which can be achieved in a community.

Water quality is most important where water-borne diseases, such as typhoid fever, cholera, hepititis, and the varieties of gastroenteritis are of principal concern. In contrast, water-waste diseases, such as trachoma, conjunctivitis, and dermatitis are less sensitive to water quality improvements than to increases in water availability.[1] For a more complete discussion of this topic, also see Chapter Five in Feachem, et al., Water, Wastes, and Health in Hot Climates.

As Carruthers points out, many of the cities in developing countries have water supply systems which are over-extended and operating above design capacity. This leads to a general, sometimes serious, deterioration in the quality of service, e.g., low pressures, contamination of mains with sewage, private investment in expensive, supplementary water facilities, use of polluted alternatives, etc. Even where supplies are operated near or above capacity the level of service is often minimal, taking the form of public standposts.[2]

Water supply problems range from the lack of adequate delivery systems to the lack of sufficient water resources for domestic and industrial uses. Water quality problems result from inadequate sewerage and waste disposal system, and contamination of large bodies of water which supply urban areas. Sewerage, the

conventional method of human waste disposal, requires massive investments of both foreign and local capital which are generally not available in developing countries. Where sewerage systems have been built, they have often resulted in charges to the consumers which were beyond their ability to pay. Water treatment facilities capable of treating beyond preliminary stages are rare because many facilities do not operate efficiently and experience frequent and lengthy breakdowns.

A large percentage of the world population does not have access to potable drinking water, and an even higher percentage does not have assess to sanitary disposal of sewage, resulting in a full range of water-borne diseases. According to 1970 estimates reported by Saunders and Warford, well over one billion persons in developing countries are classed as a "dispersed" population with only about 14% having reasonable access to a safe water supply. Obviously, the remaining 86% currently have access to some source of water, frequently in meager quantity and quality. In many countries, only a very small percent of the population has piped water, and raw sewage is dumped into streams without any treatment. In the urban areas of Africa, for example, the majority of the population is not hooked to the piped water system. Rather, water is distributed through hydrants on public spigots, and carried to homes in open containers. While perhaps officially prohibited, public faucet areas are often gathering places for people washing clothes, dishes, etc.

Quite often houses which have private water connections are not joined to the sewage system. Septic tanks empty directly into open ditches, rivers, streams, and coastal waters. In Indonesia sewerage facilities are almost non-existent. Human waters are disposed of in pit latrines or septic tanks. Further, many countries' drainage systems are not designed to handle the yearly floods, and large areas of these cities are periodically inundated by contaminated waters. Also, in the vicinity of sewer outfalls, the sea water along beaches can often be heavily polluted.

Water Sources

Water supplies are generally developed from wells (drilled or dug), infiltration galleries or protected springs, all of these being ground water sources which usually provide a reliable and safe source of water and can be protected much more readily than surface water. Surface water sources may be subject to competing demands. According to circumstances, streams, lakes or manmade reservoirs may be chosen for development of water supplies. To protect these water supplies from contamination by human excreta, the methods and location for disposal of excreta must be identified and given high priority.

Sundaresan's case study in India provides a discussion of the merits of slow sand filters and rapid sand filters as treatment methods. He comments that evaluation of existing water treatment with these two filtering techniques indicate that slow sand filters have a better capacity to withstand low operational skills over long periods of time. In addition, he indicates that the cost of chemicals and energy are increasing at such a rate that rapid gravity filters may prove to be uneconomical even at higher capacities in the near future.[3]

Water distribution systems must be designed for continuous operation. Intermittent operation creates conditions for negative pressure and increases the possibility for contamination through cross-connections. Adequate pressure must be maintained throughout the system and positive measures for control of water wastage must be instituted.

Location Sensitive Factors

The literature has shown that water distribution may stimulate changes in land use. Settlements may cluster near the supply points. Transmission pipelines may stimulate settlement at points along the line if access to the water is allowed. Water demanding industries and other services, such as clinics and schools, will be encouraged to locate there, stimulating immigration and community growth. The abandonment of an existing source

may likewise lead to shifts in settlement patterns. Water distribution points need to be located and constructed carefully to avoid developing health hazards and nuisance from poor drainage of spilled or wasted water.

Human Environment

The primary effect of water supply on people is improved public health due to a greater quantity of domestic water and, to a lesser degree, higher quality of the water, as well as to the sanitation that is introduced. Time saved in transporting water may be utilized in more productive activities, especially for women and children, although this benefit frequently is not realized, due to social conditions and local customs. If meaningful and economically attractive jobs are not provided to fill the time void created by the new water system, very little incentive will exist for the maintenance of the system.

Planners should be alert to the possibility of creating conditions that increase the likelihood of diseases. Basic control measures can include preventing contact of man and animals with the water supply.

Overview of the Literature on Water and Waste

The World Bank has supported various efforts by Rybczynski, et al. and Kalbermatten, Julius, Gunnerson, et al. in assessing the state-of-the-art from the literature available. What was reported is extremely useful. Very little data exist on deposition. Though designs for water-seal toilets and squatting plates are often described, few actual experiences are documented. It seems likely that deposition devices play a key role in public health, and work is being done to improve designs, based on field surveys. If local solutions could be reported and documented, which is difficult, it is very likely they could be adapted from one region to another.

The septic tank is the focus of the literature on on-site collection and treatment. Although widely used in the United

States, it is not generally appropriate to a developing country because of expense. The more adaptable pit latrine tends to be ignored. In Botswana, Wilson reports on low-cost developments dating back to the early 1970s when the government undertook initial work on fiberglass aqua privies. Two questions persist: how the operation of the pit latrine could be improved to overcome problems of flies, smell, and cleanliness; and how the nontechnical aspects of rural latrine programs contribute to their success or failure. Much of the literature assumes the latrine to be a purely technical problem, though it is clear that fecal habits are instrumental in rural and urban sanitation programs. Most of the literature takes for granted that privies are a secondary solution, "ignoring the fact that for many urban slum dwellers they have been, and will likely continue to be, the only affordable solution".[4] As Rybcznski observed, the literature has not resolved the question of using urban pit latrines or composting toilets, i.e., ideas for improvement, identifying risks and limitations.

Sewage treatment for developing countries is the focus of the literature on collection and off-site treatment. The subject of stabilization ponds is thoroughly documented by researchers in both developed and developing countries, though the method of getting the excreta to the pond remains unexamined. Not enough operating data are known concerning truck collection, even though this system is quite widely used. Not much information exists on the various cart and night-soil conservation systems that are practiced throughout the developing countries, even though these form the backbone of existing urban waste disposal.

Rybcznski further indicates that the reuse of treated sewage and sludge is well-documented in western literature as it relates to irrigation and aquaculture in both hot and temperate climates. What is not well-documented is the use of night soil as practiced in fertilization and fish culture. Biogas technology is well-documented, especially in the Indian literature.

A number of water-saving techniques are described in the Western literature that might have application, particularly in areas with water supply problems. Even though the population served by sewers in developing countries is small, their proportion of water consumption is so high that water-saving measures could play an important role.

In general, the differences in climate, socioeconomic conditions, and the nature of the problem make it difficult to apply technical data from an industrial country directly to conditions in a developing country, even when the data are of a "scientific" nature. This is particulalry true with respect to nonconventional technologies. Any attempt to upgrade or improve the situation will have to be based on complete understanding of existing conditions, limitations, possibilities and resources.

ISSUES AND PROGRAMS

A review of the literature and country case studies highlighted several factors which are considered essential for the application of water and sewer programs.

Water Resource Management

Large areas of impervious paved surfaces, a result of urbanization, increase the amount of water runoff generated. This often aggravates flooding problems. Investigators have pointed out that flooding becomes a problem when development encroaches upon the low ground adjacent to rivers or shoreline subject to natural and periodic inundations. This problem can be long and costly. Flood drainage is increasing in the U.S. and other countries despite the expenditure of money for flood control in the national level. Neither complete flood control nor abandoning the flood plain is a feasible solution.

The literature also indicates that encroachment in the flood plain by filling is a common problem. While filling can prevent flood plain drainage to an individual development area by raising

it above the flood plain, it tends to increase the depth and velocity of flooding in other areas. The Urban Land Institute's literature, geared primarily to the developed countries, cites the development of small impoundments on stormwater catch basins for flood control.

Attention must be given to proper water resources management in their operation. This includes the integration of ground and surface water management and the development of sound maintenance and drainage practices. Water scarce areas must also receive special attention and treatment. They may require more capital intensive irrigation technologies and will certainly demand the introduction of new strains of crops and vastly improved farming and range management practices. In many cases, the fragility of environment may dictate the continuance of comparatively low yields per acre.

All new irrigation practices must be designed on the basis of a recognition of their environmental impact: they should avoid land degradation through water-logging and soil salinization; they must be designed so as to limit the spread of waterborne diseases; and they must permit reasonably simple use and maintenance.

Conservation of Water

The essential objective of any water scheme is to provide water of adequate quality and in sufficient quantity at the right place and at the right time. This objective can be frustrated by bad design, poor maintenance, or pollution.

Waste of water occurs in both rural and urban water schemes. The efficiency of water use is notoriously low, especially in irrigation. As indicated earlier, substantial losses of water occur in urban distribution systems. In many urban systems, up to one-half of the apparent daily consumption is lost through leakage and waste. The corollary of this, of course, is that if waste were reduced or eliminated it would be possible to supply a large number of additional people with good water at low cost.

In fact, conservation generally represents the most economical source of new water supply.

Conservation can and should be pursued in a variety of ways: planning, management, technology, and education. Planning the preservation and management of watershed catchment areas can make an enormous difference to runoff and supply. Recycling, desalinization of brackish water can both extend and augment supplies. In other areas, demand management may be the answer. Demand may be reduced by providing incentives to people to install water saving devices.

The efficient operation of a water project can be encouraged by economic measures. User charges can demonstrate that water is not a free good, and where the charges increase directly rather than inversely with use, they can provide a powerful incentive for conservation.

Education programs designed to encourage and demonstrate programs designed to show water users how to reduce waste are often very effective. The literature reveals that when these programs are supported and extended, results are very positive.

Institutional and Managerial Approaches

The literature overwhelmingly stressed that the development of sound strategies and the formulation of programs for water and sewer requires an effective institutional and managerial infrastructure and definition of administrative and technical procedures. Strong government commitment and support is a major prerequisite for success of any development program. Clear examples are found in countries like the Dominican Republic and Brazil where, by establishing a national institution and policy and by implementing a dynamic program of education, consultation, stimulation, success was ensured. Experience from early ventures in the development of water supply programs has shown that the most common reason for failure in follow-up on investment in developing countries was the absence of a sound and viable organizational structure.

Institutional and managerial arrangements embrace a range of interdependent factors, e.g., resources, including human resources, channels for rapid communications, intersectoral coordination, access to and acceptance by the community, enabling legislation, and a full body of information on technology. Such arrangements are required at all levels from centralized planning at the national level through project preparation and implementation at the local level, to ensure the effective use of available resources in support of community based activities. A critical review of the existing institutional framework and its management can facilitate governments' identification of existing weaknesses and the extent of reform required.

A sound institutional and managerial infrastructure will also assure adequate training of staff in the construction, operation and maintenance of water supply and sanitation facilities. Education of the public in the acceptance and use of such facilities is important. Especially important, as Elmendorf points out, is the inclusion of women in all aspects of the process. Women are managers of household water supplies, and, whether recognized or not, women have a strong potential role as managers of community water supplies as well.[5]

Socio-Cultural Factors

In the past, water development schemes have been far to dependent upon imported capital intensive models. Too much attention has been paid to expensive engineering facilities and too little to the social preconditions for success. The results are well known -- often excessive mechanization with resultant income increases for the rich and unemployment and migration for the poor. Inadequate maintenance of the supply system, irrigation and drainage facilities results in low water efficiency and yields.

The socio-cultural and economic differences between the population in different regions or countries should be recognized. The concept of commercialization of water supply, let

alone a profitable one, has seldom gained acceptance in many areas in developing countries. The system should not only be technologically feasible, but also economically viable and socially acceptable and relevant.[6]

Community Involvement

In many countries, it has been found that one of the principal causes of failure has been the lack of participation of the citizens in every phase of the local water and sanitation scheme and the lack of contribution to its construction and operation. The project literature for existing community water programs has shown that participation in the early stages of project design greatly contributes to the success of the project. The choice of alternatives and the level of service are decisions in which the community can be usefully involved.

IMPLEMENTATION AND MANAGEMENT APPROACHES

Water Loss

One of the most common problems encountered in many water systems is the large quantities of water lost or wasted after entering into the transmission and distribution systems. Losses result from leakage in poorly constructed systems or when pipes become corroded from illegal connections, from meters which under register, and from records which have been lost on customers receiving service. Because of the economic consequences of large water losses, including the health hazards of poorly maintained systems, technical sections of every water institution need to give high priority to prevention and correction of water losses. Consideration of metering policy should represent a deliberate choice of the extent to which consumer connections are metered. Some practices which may need attention are administration of the billing and collection system, meter reading procedures, measures to avoid graft, and illegal connections.

When the area or line in which there is a leak is known, a pipe locator should be used to determine the exact location of the pipe. A listening stick applied directly to the pipe or to the ground surface above a pipe can be very effective in transmitting sounds to the ear. Amplifying devices such as stethoscopes and special equipment exist, but there is no evidence that pipe locators or amplifiers are better than a listening stick for distinguishing the noise of a leak from other noises. Their advantage is that they produce a louder output. An extensive and useful summary of leak detection in India has been published by the Central Public Health Engineering Research Institute.

Technologies

In the field of water supply, work is already well advanced. New designs for hand pumps have been prepared and tested for rural areas although much work remains to be done to overcome the chronically high failure rates of hand pumps. Designs for low-cost water distribution networks providing a mix of house connection and standpipe service to urban slum and squatter communities are already being implemented. The institutional infrastructure needed to efficiently expand service at a rapid rate, and the tariff policies necessary to cross-subsidize it, have already been developed in many countries. Achievement of global targets for water will depend more on mobilizing funding and the training of sufficient staff to expand present programs than on the need to develop new ones.

For sanitation, however, few attempts have been made to develop or implement technical options for a developing country other than waterborne sewerage. What is becoming very clear, however, is that waterborne sewerage has proven to be technically, economically and culturally unsuitable for many cities and communities in the developing world when it has been tried. Even in industrial countries, the enormous water requirements and very high environmental cost of the point discharge of treated waste necessitated by sewerage are leading to a re-examination of

this desirability. Thus the first step toward the rapid expansion of water and sanitation services is a thorough and critical examination of the technological options available.

Use of Appropriate Technologies

Technology options in implementing water and sewer programs in different parts of the world, with their varying degrees of development, rural and urban character, socio-cultural attitudes, and geographical nature, are complex and pose a challenge to the professionals at all levels. Technological innovations of the developed countries have often had a limited impact in the urban areas and little if any impact in the rural areas of developing countries.

Appraising a program of appropriate technology is very different from appraising individually suggested technologies. A program to research new technologies, adapt existing ones to local resources and needs, and promote acceptance among agencies and communites involves different activities than those used in applying a particular technology.

Kalbermatten points out that a considerable amount of literature on appropriate technology has recently been developed, especially in manufacturing and aquaculture. According to Kalbermatten, E.F. Schumacher in his book Small is Beautiful (1973) is credited with generating tremendous interest in this topic by bringing some of the basic points into public view.[7]

The aims of appropriate technology are to: (a) reduce unit costs of improvements in water/sewer systems even at the expense of standards applicable for the most modern technology; (b) be simple to operate and maintain with knowledge taught at the levels it is applied; (c) encourage national foreign exchange savings and creation of local employment; (d) allow continuous up-grading if and when local incomes can be increased; (e) produce significant health benefits.

These technologies have several criteria: that they be (1) scientifically and operationally effective; (2) acceptable to the municipality, i.e., they recognize local socio-cultural constraints; and (3) tailored to local resources of manpower, technical knowledge, financial and economic means. The ability and willingness of a community to pay for a scheme in cash and labor contributions will influence the level of technology chosen, the organization of the decision-making process, and the construction and operation/maintenance of the scheme.[8]

On-Site Options

Investigations of on-site sanitation systems in many communities around the world have provided a wealth of practical design and operational data.[9] All of the urban options identified generally require large-scale activity in the planning phase, whether to design a sewerage network or to organize a truck and vault system. The same is true of the on-site options -- adequate systems must be designed and information disseminated throughout the community. The unique characteristic of this option is that the on-site options can be implemented and operated by the individual.

The simplest on-site system is the pit latrine, which is the most commonly observed technology around the world, particularly in rural areas. When the pit is about three-fourths full, the superstructure and squatting plate are removed, and the pit is filled up with soil from a new pit dug nearby. There are reports of urban pit latrines working satisfactorily in India and Jakarta. The possible density of use of pit latrines varies greatly with soil conditions. In African projects, pit latrines are used with population densities of up to 150 persons per hectare.

Rybezynski indicates that the most common on-site treatment in the industrial countries in rural areas is the septic tank, better known as the acqua-privy in developing countries. Because it is a wet system, the aqua-privy is limited to soil conditions

even more than the pit privy. The installation of aqua-privies connected to mini-oxidation ponds has been proposed in Manila for those who cannot afford sewerage. Some modification of this approach might be relevant in certain cities. In Belize, for example, aqua-privies have been proposed as public latrines. Although the literature identifies this option as "appropriate technology", operational difficulties still exist.

One of the waste treatment systems reported is the compost privy. The largest single example is the Vietnamese program of anaerobic composting toilets, which is primarily a rural technology with some application for urban areas. There have been suggestions that the aerobic composting toilet could be adapted to urban tropical conditions, but so far this has only been done on a pilot scale in Tanzania and in Manila.

Rybczynski suggests that composting privies should not necessarily be regarded as "interim solutions." "Although greywater could be disposed of by surface drains, this could ultimately be done by underground pipes, while maintaining a dry on-site system for excreta disposal."[10] They are successful in both developing and industrial countries when they receive a high degree of user care and attention. This technique is most likely to occur when there is an urgent need for fertilizer or when there is a high degree of environmental concern.

In judging the overall cost effectiveness of on-site technologies is the provision for adequate system maintenance and management budgets. These systems, which may include combinations of individual home treatment units, clustered units, small centralized treatment with surface or subsurface disposal, along with various combinations of pressure or vacuum sewer collection, are generally more widely dispersed than conventional treatment systems and therefore require greater than normal attention to operation and maintenance equipment items.

Off-Site Options

One of the technical problems with sewerage in low density areas in tropical climates reported by Rybezynski is a tendency to clogging because of insufficient water usage. This is particularly true in arid conditions, or when only a small part of the population can afford to be connected to the sewerage system. The aqua-privy/sewerage system has been proposed to overcome this problem. This system uses conventional aqua-privies connected to sewer pipes with the vault acting as a settling tank for all the solids allowing only liquid overflow to pass into the sewerage system. The smaller quantity of water reduces treatment costs. In Zambia, problems of clogging and desludging of the vault have been reported. The latter is reported to be the result of heavy construction activity, which obstructs access to the vacuum truck. Rather than being an inherent failing of the system, it is viewed as a result of poor planning. The acqua-privy/sewerage system is cheaper than conventional sewerage, however, the saving is marginal and the capital cost of pipes, trucks, and vaults is high.

Where waterborne systems are already in use, or where they represent the only viable option, two points should be kept in mind: the reuse potential of the wastewater, and the quantity of water consumed.

Some of the capital cost of the sewerage system can be recovered by the development of algae production and fish ponds and secondary use of water for irrigation. In Yemen, for example, one of the constraints on the proposed sewerage system was that the water, because it was considered such an important resource, should be recharged to the aquifer. Experience has shown that most urban sewerage projects expend funds in underground pipes and inevitably approach disposal from a short-term "least cost" point of view. This leads to primary treatment and river disposal, as in Rangoon, instead of taking advantage of the long-term benefits of reuse.

Cartage Options

A key principle of sewerage is the removal of human wastes to other locations for treatment and/or disposal. Several options for human waste removal exist that perform this without the need for underground pipes: handcarts, trucks or vacuum trucks, depending on the level of sophistication. The cities of the developing countries use cartage quite extensively as do the cities in China, Japan and Taiwan.

The technology of cartage is not complicated. The main criticism leveled against it is the high degree of efficient central organization required for successful operation. The cartage system always operates at full capacity from its inception. This contrasts sharply with piped sewage schemes, which may not operate at capacity for many years after beginning construction. The costs of cartage systems vary from case to case, but two factors stand out: the frequency of collection, and the distance from vault to disposal point. In most Asian countries, the contents of the vault are pumped out regularly.

It is Rybczynski who pointed out that very little study has been directed toward reducing the cost of vacuum trucks or on low-cost methods for night-soil treatment. Vacuum truck systems from advanced countries will very likely have to be altered to meet the conditions in the less developed countries. Smaller-scale vehicles, such as hand-operated vacuum carts, which could be locally fabricated, would make the cartage system much more adaptable to incremental adoption by the informal sector.

One of the advantages of cartage is that it can be used to upgrade conditions in existing built-up areas, where the construction of underground sewers would be impossible. Cartage can also be used in conjunction with on-site systems. An example of this is reported in Jakarta where existing cesspools have been used by periodic cleaning, in spite of high groundwater and poor soil conditions. It was found that the cost of this service was affordable by the low-income community.

Rybczynski goes on to report that the vacuum truck and the smaller version vacuum cart are the only cartage systems that can be hygienically operated. These systems can extract the night soil directly from the vault thus avoiding the problems of odor, uncleanliness, and unpleasantness associated with the pail or bucket systems, both for the user and scavenger.

Resource Recovery

Resource recovery refers to a broad range of programs which have as their ultimate goal the recovery of energy and/or material from the solid waste stream. Resource recovery facilities usually refer to capital-intensive, "high technology" systems designed to recover energy and/or materials from solid waste through a variety of mechanical, chemical and thermal processes organized in either centralized on decentralized sites. Energy can be recovered in the form of steam, electricity, and gaseous, liquid and solid fuels. Materials which can be recovered include paper, glass, aluminum, iron, tin, compost and animal fodder.

The technology for converting solid waste into fuel is relatively new and is developing rapidly in the industrialized, more developed countries. All of the systems under consideration or in use today were conceived since the mid-1960's. Nevertheless, several full-scale projects are presently in operation principally in Europe, the U.S. and Japan. Furthermore, many communities are proceeding to implement full-scale systems.

Implementing a solid waste energy resource recovery progam is a very complex and costly undertaking even for the wealthiest cities and countries. It is considered a sophisticated "high technology" alternative where its successful implementation is dependent on many factors.

Biogas

A mixture of gases containing 55-65 percent methane is obtained from the anaerobic decomposition of organic materials. This process occurs in nature (yielding swamp gas, for example), and gas has been produced in controlled environments for many years in certain types of sewage treatment plants. It can be produced for use of biogas plants for individual families or by villages to provide fuel, improve sanitation, and increase the fertilizer and soil-conditioning value of animal dung and other organic wastes.

A biogas digester consists basically of a sealed container filled with water and the material to be digested. Gas produced rises to the top of the container and is extracted through a tube or pipe. In most designs, an upper portion of the container is reserved for gas storage. Raw materials are generally added through an inlet at one end of the digester and the digested "sludge" withdrawn via an outlet at the opposite end. A wide variety of designs is under development. The process by which biogas is produced is complex and not fully understood but involves at least two types of bacteria. Production is sensitive to temperature, acidity or alkalinity, and to the type of feedstock used.

China and India both have large-scale biogas programs. The Indian program involves technical assistance and subsidies on construction costs and has reportedly resulted in the construction of some 37,000 plants. The program was criticized on the grounds that the benefits from the units initially promoted went to the relatively wealthy families who had the cattle, land, and credit needed to build and use them. These units cost US$240-360, several times the average annual income per capita in rural areas, and reduce the availability of free dung, so that the program had a negative impact on the real income of the poorest groups. The program is now giving greater emphasis to community-sized plants.

It is reported that over seven million biogas digesters have been built in China. Most of these are said to be family-sized units. The Chinese designs are simple and well adapted to do-it-yourself construction and reportedly require a cash outlay equivalent in Chinese prices to roughly one-quarter or one-third the average annual per capital rural income. A large part of the credit for Chinese success with biogas is also due to an intensive extension effort.

Most of the other Asian developing countries have from ten to a few hundred biogas plants in operation. They appear to be very successful in the Republic of Korea (where they are not operated during the winter). There, as in China, the main feedstock is pig manure, which has technical advantages over cow dung.

Although there has been no dearth of studies on the economics of biogas, no consensus has emerged. Cost-benefit analyses of the comparatively well-documented Indian experience have yielded various conclusions reflecting the widely different assumptions made about the economic cost of dung, the quantity and value of the labor required to operate the digester, and the value of the gas and sludge as fuel and fertilizer. The only points that seem to clearly emerge from these studies, taken together, are that the economic assessment of the biogas digester requires more definitive work on the methodology and values, and that careful study of the specific socioeconomic context is essential to the proper evaluation of individual projects. There is also clearly a need to broaden the base of experience on which economic analysis has been based and, in particular, to assess the implications for biogas economics of apparently less costly Chinese designs.

Water Rates and Pricing Structure

The cost of providing water service has increased dramatically over the past decade. These increased costs have translated into much higher user charges to the customer due to

several factors influencing pricing: upgraded and more sophisticated equipment requiring increased maintenance costs; inflation, which has had a more significant impact on commodities and services affecting utility operations (chemicals, electricity, salaries, etc.); and requirements of operations which need more qualified managers and operators. As a result of these and other factors, government officials and utility managers have been forced to examine water and sewer user charges and pricing structures affecting their communities more carefully.

Comparing water and sewer rates among communities can provide insight into pricing policies of water and sewer utilities. Care should be taken, however, in drawing conclusions from this comparison. Lower water rates for a community may not necessarily mean the utilities are well operated and managed. Conversely, high rates may not mean the utilities are poorly operated and managed. Many factors affect the cost to be recovered through the pricing structure. Some of the most prevalent factors include:

- Geographical Considerations. Geographical location and topography significantly affect the cost. For example, in mountainous areas, pumping and transmission costs can be major systems costs. Water treatment plants located far from the source of water supply can have high water supply costs. If it exists, a waste treatment plant located far from its discharge stream can have high disposal costs.

  Another geographic consideration is customer density. In areas where connections are dense, average collection and distribution costs tend to be lower. In communities where customers are more dispersed, collection and distribution costs can be significantly higher.

- Demand Considerations. Customer demand plays an important role in developing the size of the facilities, and therefore impacts water rates. In a conventional system, household delivery increases the cost substantially over a public standpost system. This runs counter to the basic goal of reducing cost. Facilities have to be designed to provide for seasonal and hourly demand, as well as potential growth in a system. Peak demand usage may be significantly higher than average usage of water. As

a result, customers may have to pay a relatively high rate during non-peak periods to have facilities available to be used during peak periods.

In conventional systems, it is common practice to design the source and transmission facilities to meet maximum day demands, while the distribution system is designed to meet peak load conditions. The operational storage facility is usually the place of transition from maximum-day to peak-hour flow rates. Since peak conditions only occur for a brief period each day, the distribution system is not being fully utilized at other times.

Resort areas provide a good example of the impact of peak demand on water pricing. Facilities are sized to meet vacation demand and have high facility costs when computed on a average annual gallon basis.

- Age of the System. Typically, older systems require more maintenance. In new treatment systems, however, an extraordinary amount of maintenance may be required to work out the "bugs" until the facilities are operating efficiently. Also with a new system, significant financing costs may be required as compared with older systems where debt has been repaid or the debt is based upon much lower historical costs evaluated to determine operating and capital revenue requirements and the impact on the rate comparisons.

- Level of Subsidization. Many public water and sewer operations fall organizationally under a municipal government or special district or authority. The municipal government often provides administrative services which benefit water and wastewater operations. These services might include personnel services, purchasing, administration, accounting and data processing. If the general fund does not recover sufficient administrative costs from water or sewer operations, a subsidy to water or sewer operations could result. On the other hand, an overrecovery of administrative costs from water or sewer operations could result in a subsidy to the general fund. The subsidy concept could be extended to include subsidizing more than administrative costs.

- Other Evaluation Criteria. Other factors influencing the comparison of rates include levels of efficiency, organizational considerations, and such demographic considerations as availability of labor, compensation scales, and levels of employee training.

In summary, care should be taken in drawing conclusions regarding water and sewer operations or management in a particular community. Many factors influence pricing. Comparisons among communities could signal to management, however, that there should be reasons why one community's rates are higher or lower than another community's.

Community Participation

As emphasized earlier, a project, to be viable, must be within the range of charges affordable by its users. The rate of charges may include the recovery of capital costs and cost of operations, maintenance and management measured against some unit of service volume of water supplied. Participation by the community and its leaders at the planning stage is important to ensure that the services will be used and maintained as planned. In Haiti, for example, where local water supply projects are given high priority, the government has found that installing a portable water system without firm local support is not workable. Learning from experience, the government has provided water to a number of villages under a system wherein a committee of local leaders arranges for labor inputs, engenders local support, selects the method of charging, and administers the operation of the system. The level of local involvement attained in Haiti is exceptional, but this success underscores the advantage of involving the beneficiaries at every level of project planning and operation. Malawi is another country where success has been achieved through community involvement in water supply projects.

Institutional Constraints

Institutional constraints often prevent the satisfactory operation of water, sewer and waste technologies even when they are properly designed, due to lack of adequate maintenance (at the user and/or municipal levels) because the users and some

municipal officials may not be fully aware of the need for maintenance. Thus, user education programs for institutional development mentioned previously will generally form an essential part of sanitation, water, sewer or solid waste program planning. Changes, especially those in social attitudes, can be accomplished only slowly, with an emphasis on the value of a planned series of incremental improvements over time.

LIST OF FOOTNOTES

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2. L.D. Curruthers, Impact and Economics of Community Water Supply: A Study of Rural Water Investment in Kenya, p. 2.

3. B.B. Sundaresan, "Water Supply and Sanitation Options in Developing Countries - A Case Study (India)", p. 131.

4. W.C. Rybcznski, et al., Low-Cost Technology Options for Sanitation, p. 44.

5. Mary Elmendorf, "Women, Water and the Decade", p. 9.

6. Sundaresan, op. cit., p. 123.

7. J. Kalbermatten, et al., Appropriate Technology for Water Supply and Sanitation, A Planners Guide.

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VI. SOLID WASTE MANAGEMENT*

* This section of the report was influenced to a large degree by the work of Sandra J. Cointreau, a consultant to the World Bank, whose report entitled Environmental Management of Urban Solid Wastes in Developing Countries will be published by the World Bank shortly.

VI. SOLID WASTE MANAGEMENT

INTRODUCTION

Importance of Managing Solid Waste

Management of solid wastes (most widely referred to as refuse) is of growing concern throughout the world. As populations steadily increase in the urban and rural areas of developed and lesser developed countries, many of the rural poor move to small, intermediate and large sized cities, placing additional burdens on existing sanitation systems. More times than not, these existing systems are already inadequate. In addition, expanding industrialization and consumerism contribute significantly to the problems of waste management, considering the increased amount and types of refuse. In the cities of developing countries, particularly low income areas, refuse is not collected. It is because of the need for sanitary methods of solid waste disposal, in mitigating the hazards of contaminating public water, that the United Nations has called upon governments to give priority in their development planning to the goal of safe water and related sanitation measures in every community by 1990.

The management of solid wastes is difficult in any country since it requires a combination of land, labor, capital, management and planning on a continuing basis. Often national and local governments are not fully aware of the many options in equipment that can reduce long-range costs and labor/management problems and assure the success for the solid waste system. In addition, the range of alternative techniques that have proven effective and promote low-cost operations are often overlooked in favor of more capital intensive, mechanical approaches. Quite often most cities have never developed a master management plan for their refuse that can be followed and that allows for equipment alternatives and changes.

There are various health and environmental aspects associated with solid waste. Environmental concerns in these areas focus on disease vectors arising from decaying and fecally contaminated waste. The need for sanitary methods of solid waste disposal in developing countries is evidenced by commonly recurring open refuse piles of waste dumped in the streets, disposed of in empty lots, canals, rivers, or drainage ditches, and which often contain human fecal matter. This situation creates potential hazards in both rural and urban areas leading to clogged drainage ditches, sewage pipes and canals, causing flooding and polluting sources of water supply.

When considering that human excreta is a critical vehicle for transmission of a wide range of communicable diseases, Cointreau points out that municipal refuse is often overlooked as an important pathway for the pathogens contained in human feces. It is well known that solid wastes, particularly those of animal or plant origin, attract insect and rodent pests and vectors.

There are three principal health and environmental characteristics associated with the mix of solid wastes:[1]

(1) Human fecal matter contained in most municipal refuse, because of inadequate sanitation facilities and co-disposal of night soil with refuse

(2) Industrial waste (also contained in municipal refuse), due to the co-disposal of business wastes (some of which may be hazardous) within the municipal landfill

(3) Decomposition by-products of materials within urban solid waste, many of which contaminate ground or surface waters through seepage.

Transmission of communicable diseases occurs directly through refuse collection workers, scavengers, or playing children, and indirectly through such vectors as flies and cockroaches.

The literature reveals that management of solid wastes has historically received very little attention. In the past, problems of solid and liquid waste disposal in the urban areas of lesser developed countries, and to a certain extent in developed countries, has been either completely neglected, ignored, or approached by attempting to apply collection, treatment and disposal technologies used in the more developed countries of Europe and North America. Urban communities in developing countries have been approached by representatives of companies and engineering consulting firms who have promoted refuse management solutions with inappropriate and expensive approaches. Since they tend to impose a financial burden beyond the means of the municipality, very few of the sophisticated approaches have been adopted. In addition, these systems demand highly technical personnel to assure the proper planning, operation and maintenance of the system. The problem of small and intermediate size cities has usually been ignored, quite often because of the lack of financial means and political power of provincial cities.

Therefore, while good solid waste management will not solve all of the problems of sanitation in the rapidly growing communities of the lesser developed world, sound solid waste management can contribute significantly to good public health, welfare and environmental quality. By controlling and properly managing wastes, many diseases can be effectively reduced or controlled. In addition, the potential for recovering or reusing at least a portion of the waste stream may have a positive economic effect on the community, especially upon the financing of urban facilities, a factor that will become increasingly important as the competition for municipal funds among the transportation, housing, and other municipal services and needs intensifies in the coming years. Moreover, as some of the literature indicates, it may be that without the creation of commodities, such as biogas,

recovered materials, recycled fertilizers, etc., from the municipal waste stream, the community may not perform all the health and sanitation functions of total solid waste management, i.e., collection, treatment, and disposal.[2]

Categories of Solid Waste

Categories of solid waste most often used are as follows:[3]

- Household garbage and rubbish: wastes resulting from household activities (e.g., food preparation, fuel burning); yard waste and other bulky wastes may require special collection systems.

- Commercial refuse: wastes from business consisting typically of packaging materials, used office supplies and food; refuse generated from markets containing many small vendors present particular storage and collection problems.

- Institutional refuse: wastes from schools, hospitals, government buildings, etc.; content varies according to type of institution.

- Street Sweeping: includes principally dirt and varying types of litter (e.g., household refuse, fecal matter); composition of waste and the ability to collect it will vary as a function of the adequacy of a city's refuse collection system at homes, offices and institutions.

- Construction and demolition debris: depends upon nature of materials used (e.g., soil, stone) and size of buildings; contractors often do not bear responsibility for removing their own refuse.

- Sanitation residues: from privies and latrines, often leading to co-disposal of "night soil" with municipal refuse at open dump sites.

- Industrial waste: includes metals, plastics, spent processing chemicals, etc.; being site-specific, special disposal arrangements are often made by larger businesses.

General Observations: Pickford discusses the wide variation in composition and quantitites that exists between developing countries. Unlike the situation that prevails in the countries of Europe and North America, the putrescible content of domestic

and commercial refuse in developing countries is appreciably greater than its paper, metal and plastic content. In many small municipalities and especially in the semi-agricultural fringes of cities, however, where such domestic animals as cattle, pigs, chickens, goats, donkeys, water buffalo, and dogs are kept close to the household, a large portion of the domestic unused food and vegatable material is fed to the animals. Many households in the Philippines, Thailand, Taiwan and China, for example, feed courtyard pigs most of the household refuse. In Middle Eastern Moslem countries, the family goats scavenge for a large portion of the vegetable wastes, while meat scraps and bones are claimed by dogs. Most glass bottles are returned for reuse, and even refuse, from the affluent sections of towns are sorted for valuable material by household servants before being disposed. In some cities, private collectors perform the collection service without charge for the value of the materials in the waste.

PROBLEMS AND TOOLS

Waste Characteristics

Current literature on typical waste streams generated in municipalities of various sizes and different socio-economic characteristics is not very extensive. Only a few surveys have been made, even though the characteristics that describe the waste streams in terms of quantity and composition vary widely across communities and countries. It is difficult to identify the nature of the solid waste stream to determine what data should be collected; it is equally difficult to collect the data once the requirements are established.

Existing infrastructure influences the composition of a community's wastes. As shown by Gunnerson and Kalbermatten, in most areas where water supply programs have been established, the sanitation programs generally lag far behind. If water supply programs are to achieve full health benefits, they must be accompanied by full-scale excreta removal programs. Thus, realization

of health benefits implies on controlled waste removal program, which can be carried out in different ways. If pit latrines are used, for example, a high concentration of solids exists. If septic tanks with small-bore sewers are used, a diluted concentration of solids must be dealt with.

This is not to suggest that data have not been collected on generation or composition of solid waste. Through direct, measured samples and estimating waste stream characteristics using various assumptions, generation rates and composition have been developed. According to Cointreau, surveys of refuse composition in India and Pakistan have indicated, for example, that ash and earth comprise between 31% and 47% of the total municipal refuse waste stream, while in Pakistan 12% of the total urban solid waste collected was animal manure and 21% was night soil.[4]

Cointreau further points out that generation rates are subject to considerable site specific factors. In general, the more affluent the community, the more waste is generated. While the U.S. generation rate is 1.25 kg per person per day, most solid waste planners for developing countries use a refuse generation rate of 0.5 or 0.6 kg per person per day. Similarly, waste composition varies widely. In the U.S., about 75% of the waste stream is combustible materials, whereas in developing countries, about 75% of the waste stream is non-combustible vegetable matter. Wastes from urban areas in developing countries have a much higher percentage of food waste in their overall refuse mix. The density of uncompacted organic refuse is about three times greater than that of inorganic refuse.[5]

Just as waste generation rates vary greatly from city to city, so do waste density values. According to Cointreau, "where refuse generation is high, density tends to be low, and vice versa. There are lower density values associated with industrialized countries due to the high percentages of non-putrescibles, such as paper, glass, plastics and metal, which often result from packaging of consumer goods." These materials have large void spaces when stored and collected. They also have low

moisture content. These two characteristics explain to some degree the low density of such wastes.[6]

These characteristics are important to the planner. As Cointreau indicates, "waste density information when coupled with waste generation rates, allow the capacity of the collection equipment to be estimated. When this capacity is then divided by the number of trips feasible for the various regions of the city, it is possible to estimate the number of vehicles to be on the collection routes each day."[7] The waste characteristics, therefore, will influence the type of vehicle or equipment needed or used. The type, size, and kind of equipment used for collection and disposal of organic waste should take this into consideration.

An important lesson can be gained from several World Bank projects. As pointed out by Cointreau, equipment designed for volume reduction by compaction is generally not justifiable for developing countries. Unfortunately, managers and engineers trained in developing countries tend to assume that technologies appropriate in these countries are equally suited to developing countries.

Traditional Social and Cultural Conditions Affecting Solid Waste Management

Several social and cultural considerations pose constraints on solid waste management. Patterns of refuse management have clearly developed historically for every city. These patterns may have some advantages that the city may want to retain and perhaps continue, or they may have disadvantages that are difficult to break. In any part of the world, the primary factor is cooperation. In development projects involving water supply systems and sanitation programs, the literature of Carruthers, White, Saunders and Warford, Bhatia and Niamiri and others has shown repeatedly that community cooperation, support, enthusiasm, and incentive have been essential ingredients for implementation, cooperation and maintenance. Implementation of a highly success-

ful biogas community project in Etawah district, Uttar Pradesh, for example, took place in a socio-economically atypical community in India. Community cooperation is determined in large part by social factors, such as the caste system and social customs. In India, contact or association with the untouchable caste by members of other higher castes is avoided because it religiously contaminates them.[8] Thus, in planning the operation and maintenance of refuse management, the degree of cooperation between the different castes must be considered.

One must also look beyond technology to the roles and attitudes of the people who are expected to use the new system or facility, particularly the women, who are the primary users of water and the socializers of their children and families in matters of personal hygiene. The lack of positive impact of various past programs is primarily attributable to non-use and misuse of new facilities, not to faulty engineering aspects. Until women are involved and understand the importance of improvements, limited acceptance can be expected.[9]

Social customs are critical in determining the acceptance or rejection of a certain management system. In the implementation of family biogas systems, psychological and religious objections to the use of human wastes for production of gas for household cooking has been documented in the literature for certain areas of India while in other states of India a great willingness to use night soil as been reported.[10] Ironically, the use of gobar gas is widespread owing to the religious belief in its cleansing value.

A number of social and cultural factors which may influence the refuse management system are discussed in the World Bank's project guide on solid waste management.[11] Probably the most obvious activity is scavenging. Many cities of developing countries have an informal refuse collection and disposal service provided by scavengers, including:

- Cairo, Egypt: door-to-door collection provided by two sets of immigrants to upper middle class and wealthly residents only; remaining residents discard wastes randomly.

- Lahore, Pakistan: farmers pick up 40% of the refuse for use in animal feed and soil amendment.

- Mexico City: municipal workers select valuable wastes and then dump wastes (for a fee) on a 160 hectare plot worked by 5,000 scavengers.

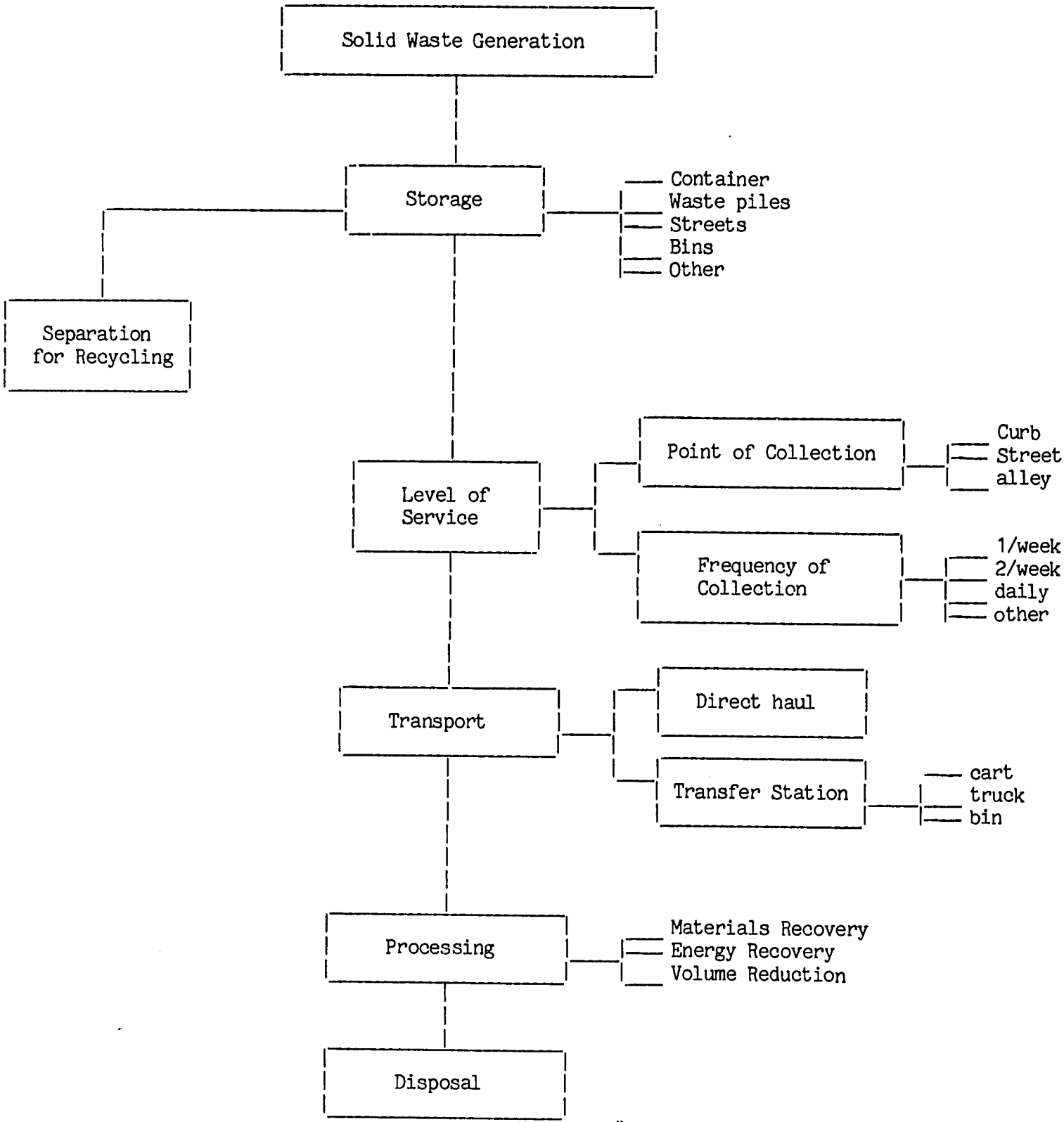
- Surabaya, Indonesia: (a World Bank-sponsored project): push cart operators dump waste at a transfer station; scavengers pick through the waste and load the transfer container with material left over, saving the cart men substantial work.

Delivery and Quality of Service

Solid waste management is concerned largely with four major functions: collection, transport, processing and disposal. Exhibit VI-1 illustrates the relationship of these steps and the range of decisions that must be made from the point of generation to the ultimate disposal of the waste. Later in this section, various technical storage, collection and disposal techniques will be discussed.

As indicated above, inequitable service exists, whether because of traditional attitudes or behavorial patterns, inappropriate technology or open discrimination. According to Cointreau, "in cases where the municipality relies heavily on an informal private sector to perform refuse collection and disposal services, there is the sizeable risk that certain populations will not be served. As discussed earlier, these populations are

Exhibit VI-1
Solid Waste Management Decision Alternatives*



* Adapted from Decision-Makers' Guide in Solid Waste Management. U.S. Environmental Protection Agency, Washington, D.C., 1976, p. ix.

likely to be the urban poor, either because these residents cannot afford a service fee, or because their refuse is not sufficiently high in recyclables to interest the private entrepreneur."[12]

Cointreau goes on to make several pertinent points about level of service:[13]

- In some cases, level of service can vary as a function of technology selected. For example, side-loading trucks work well in wealthy areas of Onitsha, Nigeria, where roads are good, traffic is sparse, and residents adhere to curbside placement of standardized containers; this type of vehicle cannot function effectively in low-income areas.

- Squatter settlements tend to be overlooked by city officials either consciously or unconsciously. This also tends to be related to the inaccessability of these settlements. Push carts are suggested to serve these areas, with wastes transferred to metal containers that can be taken to disposal sites.

- Attitudes of both low-income residents and government officials must be modified to make any system of collection work more equitably.

Storage of solid wastes at households is a simple procedure involving disposal of all refuse in a bin, can or container that is adequately covered to prevent pest invasion. In some situations household refuse is carried to communal storage bins. These must be made easy to operate, yet sufficiently secure when closed to prevent infestation. Openings should be within reach of children for dumping. Cointreau again provides a detailed description of the two principal types of storage:[14]

- Separate unit storage containers: these range from plastic bags to plastic or metal bins. Each type of container has strengths and weaknesses, often depending upon weight and composition of waste materials and outside air temperature and humidity.

- Communal storage units: either stationary or portable, with portable units being recommended so that a transport unit can shuttle several units back and forth to the disposal site (replacing a full unit with an empty one) to minimize open dumping.

Collection Techniques

Collection frequency is affected by the climate of the urban area, and the open space of the individual premises upon which waste is being stored. The hotter an area is, the more frequent are recommendations for waste collection. Odors and vector proliferation are limited by increased frequency of collection. The more densely populated an area, the more frequent the collection. Cointreau discusses three basic types of collection techniques: human powered; animal powered; and motor powered:[15]

- Human-powered: push carts, pedal tricycles, wheel barrows, etc., useful in neighborhoods with limited access. The World Bank is using pushcarts experimentally in Indonesia, the Philippines, India and Egypt.

- Animal-powered: drawn carts or saddled animals (horse, oxen), advantageous in areas where traffic is slow-moving and/or where terrain is hilly and narrow (e.g., Tunis).

- Motorized: ranging from tricycles mounted with hydraulic tipping containers to flat-bed trucks. Replacement of manual loading systems with payloaders may be desirable. Compaction mechanisms are seldom appropriate on collection vehicles used in low income countries, where high vegetable contents and low paper, glass and can contents generally limit compaction ratios to 1½:1 (versus the 5:1 ratio common in industrialized countries).

Vehicle maintenance is the number one management problem contributing to missed collections and a breakdown of the refuse service system. In the course of a day, every city generally has a number of its vehicles down for repair. No other vehicle takes the abuse of a refuse truck. It must make hundreds of starts and stops a day in traffic, often over poor roads, and then negotiate a landfill with a full load. Although driver abuse is a contributing factor to vehicle breakdowns, most vehicle malfunctions are attributable to improper truck specifications. In addition, maintenance of equipment is commonly extremely inadequate. Maintenance shops are ill-equipped, and scheduled maintenance is

rarely followed. Depots do not have a good inventory of spare parts. Since most equipment is manufactured in developed countries, parts often have to be purchased directly from the manufacturer, thus placing the vehicles out of service for prolonged periods of time.[16]

Transfer Stations

According to Cointreau, waste that is collected may be hauled directly to the disposal site, or transferred to another type and size of equipment for transport. Generally, transfer takes place from relatively small pieces of equipment to larger equipment. A useful rule of thumb regarding the advisability of establishing transfer stations is as follows: a transfer station should be used when the round trip time to the dumpsite requires more than one hour driving time, or when the haul distance is more than 25 km one way.

A transfer station can serve several functions. It is a place where the waste can be compacted, processed, or sorted and recycled. According to Cointreau, "in Jakarta, Indonesia, a pilot solid waste project includes a hand-loaded baling compaction unit in the transfer system. Waste is brought by pushcart to a platform. It is loaded into the bales for compaction into units that are sized to enable manual loading of the bales onto a flatbed truck. In this system, the need for tipping gear on the truck is eliminated, and therefore vehicle capital and maintenance costs are theoretically lowered. One problem, however, is that the bales are dense and workers tend to overload the truck relative to its design capacity, leading to higher than normal maintenance costs. Since wetlands are used primarily as dumping sites, the limited porosity of the bale minimizes the quantity of leachate which the bale could release, thereby lessening the potential of groundwater contamination. Since baled refuse is reportedly less attractive to burrowing animals, is not prone to being windblown, and is generally unattractive to scavengers, a number of landfill-associated problems are avoided.[17]

Not everyone is in agreement with transfer stations. One method for optimal collection recommended by Pickford is a relay system whereby wastes in trailers may be hauled by tractors, thus requiring fewer tractors and less fuel. He contends that double handing or transfer loading should generally be avoided due to the increased potential health hazard.

Disposal

The four basic methods of refuse treatment disposal practiced throughout the world are open dumping, composting, sanitary landfills (controlled tipping), and incineration. Of the four methods, three are satisfactory in terms of bearing on public health and environmental impact. The unsatisfactory method is open dumping.

However, open dumping remains the most prevalent form of disposal,[18] and furthermore, the dump sites are rarely sited in environmentally sound areas. The concerns related to open dumping are many and serious. Roads leading to dumpsites often are narrow and unpaved--factors that lead to long collection and disposal time requirements, especially during times of inclement weather. In addition, equipment used for dumpsites normally is in a bad state of disrepair. The situation is often made worse by an insufficiency of equipment needed to manage the entire site, whether it be to control fires at the site, or to alleviate vector and other nuisance and health problems.

The sanitary landfill is the least expensive of the satisfactory methods, provided that land is readily available and reasonably priced. A benefit of the sanitary landfill site is that it may be reclaimed for recreational use after it has been filled. In comparison, composting and incineration are more costly for community use in that they involve size and moisture regulation of the waste materials. The primary benefit of composting is the production of a reusable compost that may have several useful applications. The primary benefit of incineration is that little

land is required. Discussions of some of these options as they apply to LDCs are presented in Reference 21.

Institutional Arrangements

According to Cointreau, "there are many problems in the overall management programs for municipal refuse in developing countries. The most often encountered problem is decentralized responsibility for various activities of refuse management. Many cities have adopted a management system whereby refuse collection is administered under the department of health, disposal is handled by the public works or mechanical engineering department, and the fleet is centrally maintained for all city vehicles by the public works or mechanical engineering department."[19] Interagency coordination and planning to meet the total needs of the system are sorely lacking.

"When refuse collection is placed within the health department, it is typically at the bottom of the organizational structure. In this case, there may be supervisors assigned to administer the activities of the workers, but there are no planners and managers, and few field foremen included in the organizational framework. This is an essential municipal service with significant costs to the local government and yet receives little organizational status."[20]

As reported by Cointreau, a major concern for effective solid waste management is the creation of a responsible entity for the management of refuse for planning and managing the entire activity. As Flintoff has repeatedly recommended in his work with WHO and the World Bank, a single institutional entity should have equal status with other municipal agencies, all competing for a portion of current revenues. As a result of Flintoff's work, centralization and upgrading of institutions for refuse management have been promoted through World Bank sponsored projects in India and Indonesia.

Financing Arrangements

Inadequate financing of waste management operations is very common is most areas. In the developing countries, the availability of capital to finance refuse operations is severely limited, which in turn limits the alternatives open to the municipality. It is clear that the planner must either adopt a lower standard of solid waste delivery or seek approaches that are less capital intensive than those employed in industrialized countries.

For solid waste systems, it is essential that the operating and maintenance costs be carefully assessed. Solid waste equipment is relatively short-lived, and operating and maintenance costs are substantial. "The solid waste sector is, for example, the opposite of the water supply sector which provides large scale, often regional, infrastructure having a long life and requiring an operation and maintenance effort proportionately smaller in relation to the capital investment."[21]

Selection of Appropriate Technology

As discussed earlier, the refuse in developing countries is much denser and has a finer particle size than the refuse in industrialized countries. For that reason, much of the mechanization necessary in the industrialized countries for reduction of volume and size reduction of particles is of dubious utility in developing countries.

A combination of techniques of collection and transfer may be necessary to meet the needs of a city in a developing country. Each city is unique and possesses certain site-specific factors which make it different and thus require innovative approaches based on local resources and capabilities. Examples are the hilly areas of Tunis, requiring the use of donkeys with baskets on their backs, and India, where wheelbarrows and bullock carts are used.

The composition of refuse in developing countries lends itself to resource recovery techniques that are different from the mechanized systems in greater use in the industrialized countries. "The resource recovery options which are probably most appropriate in developing countries are based on biological decomposition of the organic matter in the waste. Because of climatic conditions which generally allow year-round, outdoor treatment by biological systems, and because of the organic and moist nature of the wastes, developing countries may find composting, biogas conversion, and methane recovery from landfills technologically appropriate."[22] Finally, careful evaluation of the market for by-products and acceptance is a critical component of the system's success.

Composting has been used extensively in many parts of Asia as a means of converting refuse and night soil to reusable fertilizer. In composting, decomposition of organic matter is controlled in a warm, moist environment by the action of various microorganisms. During this process, sufficient heat is generated to destroy most pathogens.

Generally, manual composting is recommended for developing countries. However, whether the benefits outweigh the costs is questionable. Some experts claim that the value of compost fertilizer is not worth the cost of treatment (Pickford). However, with the addition of night soil, the potential for fertilizer of compost is much greater. Other arguments against composting are that the sale of the compost product does not cover the cost of plant operation, and that in areas with already rich soil there is no need for compost. These factors must be evaluated regionally.

The literature presenting a range of resource recovery options is extensive. Many of these existing references "promote highly mechanized systems and are directed toward industrialized countries. Only incineration with energy generation has any experience among the non-biological techniques. Other systems

using such techniques as pyrolysis and refuse-derived fuel remain to be further developed in industrialized countries."[23]

"The United Nations Development Programme, in concert with the World Bank, is sponsoring a global research project starting in 1981 to develop the state-of-the-art of appropriate technology for resource recovery in developing countries. Particular attention will be given to systems that integrate more than one type of waste stream, and that integrate more than one type of technology."[24]

IMPLEMENTATION ISSUES AND STRATEGIES

Development of the Planning Process

There needs to be continuous planning activity in the development of a solid waste management program. Whether the planning function is assigned to an individual involved in operation or to a separate planning unit, the institutional arrangement should conform to whatever arrangements work for the local government.

The planning activity required as a regular function is the development of a long-term master plan in accordance with land use, economic development, water and sewer and other requirements. This requires tremendous commitment and effort in coordinating various urban activities, analysis of trends, population patterns, and development plans. It is more than planning for the traditional areas of collection and disposal of refuse. It would include strategies to develop human resources at the community level for meeting local needs, to ensure access for men and women to training programs pertaining to the maintenance, management and technology of waste management, and to recognize the increasingly effective role of women in local councils and planning boards responsible for making planning decisions.

In addition to the long-term planning effort is the short-term plan of action. Based on specific objectives to provide acceptable refuse management service, recognizing existing financial constraints, short- or intermediate-term solutions should attempt to incorporate those actions which may realize a major

improvement without major capital investment. The following offers possible activities.

a. Conduct a waste characterization survey (i.e., identify quantities, sources, types, composition)

   - Ideally, the survey should be conducted through a time period that would include seasonal variations.

   - Survey should also be conducted before any scavenging takes place so that an accurate determination of quantities and composition can be made.

   - Results of survey (properly analyzed) can be used to determine the number of vehicles required as well as the need and type of resource recovery system.

b. Optimize collection routes

c. Purchase sufficient vehicles to provide reliable service (including animal-drawn vehicles)

d. Evaluate the potential of using communal or other containers in certain areas, (i.e., high density, narrow roads, hilly, etc.)

e. Communal containers should be designed appropriately using low-cost indigenous materials as much as possible

f. Up-grade existing disposal sites or locate new ones.

g. Disposal site selection should be carried out using sound engineering principles.

h. Open dumping should be discontinued as soon as practical.

i. Implement resource recovery by organizing scavengers and providing them with equipment and a clean working environment.

j. Develop markets and uses for recovered materials; initially utilize existing marketing practices.

k. Institute pilot programs to investigate the feasibility of recovering energy and/or materials using

primarily labor intensive, low-cost methods (i.e., composting, gas recovery)

l. Review rate structure and accounting and billing procedures, and modify as needed.

m. "Adopt a system of record keeping on equipment and maintenance supplies so that an adequate supply of spare parts and materials are available at all times for typical maintenance needs, and so that an adequate lead time is given for ordering special parts for a pending repair need."[25]

n. "Assess existing laws and ordinances related to solid waste management. If required, establish ordinances that describe citizen participation in the management system, by outlining methods of household storage, placement of wastes for pick-up, separation of recyclables, acceptable dumping practices of wastes from sanitation systems, industry and commercial establishments."[26]

o. Integrate solid waste management plans with drainage, sewerage, flood control, water supply and sanitation plans.

p. Develop a comprehensive public education campaign to make the general public aware of the implications of solid waste management and obtain the public's support.

q. "Establish a competent, central workshop for major repairs and overhauls of refuse vehicles, and to the extent needed for provision of daily maintenance to some or all districts of refuse service."[27]

r. "Clarify responsibilities for the refuse by such actions as making specific collection crews responsible for specific routes or areas of service, and similarly assigning equipment to individual drivers or operators. Also, clearly designate the chain of communication and coordination for workers to utilize in reporting problems and issues in service provision, and for citizens to utilize in making complaints or recommendations."[28]

As summarized by Cointreau, "improvements of overall management and administration, followed by improvements of basic facilities serving the refuse fleet and crews, allow the activities of existing equipment and personnel to be improved. Thereafter,

if there are needs for changes in the equipment or personnel, the foundation has been established to support those changes."[29]

Establishment of Acceptable Service

Recognizing financial constraints, priorities for service must be established within the solid waste sector and among the other city services.

"Within the solid waste sector, issues to be addressed in establishing priorities and then setting standards for service include: (1) which categories of waste are included for collection and disposal; (2) what level of control is desirable; (3) what levels of citizen participation and convenience are acceptable; (4) what levels of household storage and service are acceptable; (5) what frequency of collection is acceptable, (6) which informal sectors of recycling or resource recovery should be incorporated, and (7) which environmental issues must be addressed in planning adequate disposal systems."[30]

Once priorities are established, the standard of service is very much linked to the availability of revenues, which can be allocated to the solid waste sector. If a minimum level of service is determined, as Cointreau observed, then the portion of the budget available for solid waste management becomes whatever is the least-cost amount to achieve that level. More often, the funding limit is established, and the level of service becomes whatever one can achieve within that amount.[31]

Selection of "Appropriate" Technology

As Cointreau and other authors point out, refuse costs and the selection of a collection method are affected by the cost of labor (and capital). Economic analysis of options appears to be a more important activity in selection of a system than either size of area or quantity and mix (per capita or collection point) of the waste to be collected.

Development of Institutions

The management system for refuse collection, as with any other municipal or regional service, must be compatible with existing governmental and private sector institutions. Cointreau emphasizes clear lines of authority and simple organizational structure with clear lines of communication established within each service agency and across agencies.

Arrangement of Financial Resources and Budget Planning

According to Cointreau, refuse management typically accounts for a large percentage of the municipal budget. However, cities frequently cannot account for the full costs of providing this service (capital outlays, operations and maintenance), and accurate accounting systems (particularly depreciation schedules) are essential. Budget crises often result from deferred maintenance of equipment and sudden breakdowns of a large percentage of a vehicle fleet.

Providing Public Participation and Education Programs

Cointreau identifies several components of a public media campaign that can prove cost effective: provide schedule of collection pick-up to customers; designate requirements for storage container placement and removal of yard wastes; establish a system for receiving customer complaints about service; and designate special pick-ups for recyclables.[32]

The success of a refuse program depends heavily on citizen awareness, cooperation and concern. None of these is possible without a vigorous public education campaign to explain the goals and methods of the program. Such a campaign should begin well in advance of the institution of the program. Information techniques such as radio and television announcements, posters, flyers and oral presentations are the usual modes of publicity. The active participation of local service organizations is an excellent means of developing public interest.

Public education must also continue after the program is begun. In addition, it is essential that women be included in any educational and participatory programs. Just as the importance of community participation has come to be recognized, the importance of women and their roles in community participation must also be recognized. Unfortunately, the active involvement of women in community activities is seldom practiced.

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VII. BUILDING DESIGN AND MATERIALS

* Assistance in preparation of this section of the report was provided by Donald Watson, Professor of Architecture and Environmental Design, Yale University, under a consulting agreement with Coopers & Lybrand. Consultant inputs were integrated into the text by Coopers & Lybrand staff.

VII. BUILDING DESIGN AND MATERIALS

INTRODUCTION

This state-of-the-art literature review and bibliography of building design and materials describes conceptual and technical approaches that address the issue of energy and resource efficient architecture in developing nations which are predominantly hot climatic regions.

The energy problem today in architecture affects the developing nations more severely than anywhere else. According to Flavin and Stokes [3.4, 3.5], the heating, cooling and lighting, of commercial and residential structures consume nearly 10% of the developing world's annual energy supplies. Approximately two-thirds of this energy is derived directly or indirectly from petroleum and natural gas. An undocumented, but possibly greater amount of energy is also consumed in the manufacture, transportation and import of building materials and in on-site building construction, which frequently use energy inefficient processes. The scarcity and price of fossil fuels, electricity and other building resources are one of the major drains on providing adequate and economic housing for the cities of less developed countries (LDCs).

The current architecture and energy crisis in LDCs is relatively recent. In most traditional cultures, the practice of climate-conscious design using indigenous building materials and forms was once normal. However, beginning in the 1920's, North American architects and those who trained with them from nations throughout the world, began focusing on building systems that would rely on the convenience of mechanically operated heating, cooling and artificial light [3.3]. Previously, architectural climate control was met by building designs that utilized available sunlight and natural ventilation. However, the developing nation's long tradition of low-energy building techniques and climate-sensitive architecture has too often been lost and replaced with designs from industrialized nations. One of reasons

for the decline of traditional architecture in LDCs is attributed to rapid increases in population in tandem with rapid in-migration to urban centers. Another factor is that labor intensive, traditional building designs and materials are not always easy to adapt to growing urban environments which bring with them health and fire hazard risks [3.5]. Often, the fast growth rate of urban populations has encouraged a standardization of architectural styles that are easily mass produced. Finally, a critical obstacle to the continuing use of traditional designs and materials is often the favored status now associated with living and working in a "modern" building. In many societies, traditional architecture is linked to poverty.

The end result, in terms of the energy and resource constraints, has been clear. The resulting costs involved in building has not kept pace with the demand for shelter. Today as the urban populations of the developing world expand exponentially, fewer of their citizens are able to afford adequate housing. The major challenge for architecture of the future then will be to improve shelter conditions through conservation measures.

The state-of-the-art for building design for developing nations based upon energy conservation is currently in the process of re-definition and field testing. Most technical and case-study publications focus upon energy and resource conservation in the temperate climates of the industrialized world. Research in low-energy technologies for predominatly hot-arid, hot-humid LDCs is well behind existing documentation covering energy conservation measures and applications appropriate to the West. Nevertheless, the annotated bibliographic listing at the end of this chapter contains a selection of excellent references covering most aspects of architecture and energy. These were chosen to represent the most relevant literature currently available on the subject.

A glossary of terms and basic concepts is located at the end of this section.

BUILDING SECTOR TOOLS FOR ENERGY CONSERVATION

The literature addressing building sector tools for energy and resource conservation provides valuable information on the relative importance of the three major components of the sector:

- Energy Planning
- The Design Process
- Building Materials and Methods.

Energy Planning

References 3.1, 3.3, 3.4, 3.5, 3.6, and 3.7 all discuss the tools necessary to define energy conserving initiatives. Reference 3.5 in particular includes a checklist aimed to assist a community to organize planning activities so that its design alternatives are clearly defined, analyzed and evaluated. Watson's article [3.7.] capsulizes energy planning into the following points:

- "Undertake building climatology research. Use indigenous resources.
- Develop intermediate technologies and building systems.
- Undertake community-wide conservation projects, using mutual-aid techniques.
- Use energy efficient building designs.
- Undertake building renovation projects, using self-help techniques."[1]

Concomitant to the above, Watson emphasizes the necessity to define the interrelationships between:

- Architects
- Developers
- Builders
- Subcontractors
- Suppliers

The main focus of building energy planning is the stress on techniques of climatic analysis. Building design forms must be based upon climatic design principles by integrating structural considerations and the use of certain materials to achieve human comfort and energy and resource efficiencies. The technical literature, and in particular the reference listed under the "Technical Design Documents" heading of the bibliography, relate the tasks necessary to evaluate and analyze climatic variables as the catalytic input to the design process.

Lastly, Flavin [3.3] recommends that any form of energy planning include the following considerations:

- Determine the life-cycle energy costs of existing and proposed buildings
- Get support from local/national governments to change energy standards in building codes that reflect conservation measures
- Plan for a policy to retrofit existing building for energy efficiency concurrently with new construction.

The Design Process

The goal of architectural designing on the basis of climatic variables is to conserve valuable energy and natural resources while improving human health and the quality of housing conditions. The familiar problem of modern urban buildings, offices or dwellings in Fathy's view [3.2] is that they suffer from uniformly poor design concepts which largely shield the structure from outdoor elements in order to separate conditions inside from the outer environment as much as possible. The building is then heavily reliant on mechanical devices and active systems to perform heating, cooling and lighting, all of which could be provided naturally, utilizing energy efficient passive solar design concepts. The goals of addressing the benchmarks of climate-conscious design are discussed clearly in the plenary address of the International Passive and Hybrid Cooling Conference given in November 1981 in Florida [1.1]. Basic terminology of heat energy

transfer mechanics is also clearly defined and included in the glossary at the rear of this chapter.

The general objectives of energy-saving climatic design for most climates are:

- Minimize conductive heat flow - Winter and in some cases Summer
- Promote solar gain - Winter
- Minimize external air flow - Winter
- Minimize infiltration - Winter
- Delay periodic heat flow - Winter and Summer
- Minimize solar gain - Summer
- Promote ventilation - Summer
- Promote evaporative cooling - Summer
- Promote radiant cooling - Summer

Thorough analyses detailing the methods and materials to execute these objectives are the main foci of three comprehensive sources on the topic, Evan's Housing, Climate and Comfort; Proceedings of the International Passive and Hybrid Cooling Conference by Bowen, et al.; and the Watson-Labs source, Climate Design for Home Building. [1.1., 1.2., 1.6.]

These three volumes constitute the most up-to-date and detailed sources of practical information on passive solar techniques of climate-conscious design. The elements of climatic design are presented with many examples of applicability and visual illustrations. The basic theoretical information pertains directly to hot-humid and hot-arid climates. The Evan's reference is especially useful to LDC's because of the use of metric measures. Another companion source [1.4] is a classic reference providing supplementary technical backup with climatic measurements and explanations of technical nomenclature.

References 1.2 and 1.5 are not as extensively researched or presented as are the other technical design documents but are useful in that they clearly present and summarize the main issues and options for hot climate building design practical for most LDCs. All sources delineate the distinctions between hot-humid and hot-arid conditions when plotting specific energy design strategies. Major components of passive climate design techniques involve integrating the following:

- Site selection and orientation of buildings
- Absorption, insulation, heat storage
- Shading, solar radiation control
- Roof design
- Ventilation through wall openings, mobile interior wall structures
- Air cooling, humidification, dehumidification [Type I, all; 3.1, 3.2, 3.5.]

Please note that most of the techniques hereinafter discussed may be applied to new buildings and the retrofit of existing structures to realize conservation benefits.

Site Selection and Orientation

Proper site selection and orientation of buildings are closely related to land use planning and climatic analysis. The issue of choosing construction sites involves active evaluation of the physical sites, the density of units, the size and types of units needed, and finally the location or relation of units to one another. The orientation of a building is important for the interior climate of every structure. Planning issues that precede shelter construction need to consider the following:

- Whether the potential site is earthquake prone or on a known fault line
- Whether the site is located in a heavily vegetated, swampy, or municipal waste area that would promote a

health problem with vectors, or insects that destroy wood or other building materials

- Whether the site obstructs a drainage pattern which could cause housing landslides, erosion or disintegration of building materials

- Whether the potential site is a fire hazard threat due to its location

- Whether the site can make full use of natural environmental factors that promote health and comfort for housing occupants, such as positioning a shelter for maximum ventilation and shading from heat, moisture, or proximity to potable water and sanitation facilities. [3.1, 3.2]

A major portion of the literature addressing the subject of site selection and orientation emphasizes the importance of familiarizing planners with the characteristics of the natural environment in order to efficiently and effectively utilize available resources. Measures that address conditions found in hot-humid and hot-arid climates are well outlined in SKAT's Elements of Solar Architecture for Tropical Regions [1.5] and Evan's Housing Climate and Comfort, [12] which discusses positioning and orientation of building on slopes in relation to water, prevailing winds, clustering, and proper solar orientation.

Absorption, Insulation and Heat Storage

The thermal principles of absorption, insulation and heat storage, reviewed clearly by Evans [1.2.], can be harnessed to create a comfort in cool, temperate and hot-dry climates. A comfortable room climate in a building is created by an optimum combination of air temperature, humidity, air flow and radiant temperature of walls, floors and ceilings. The ideal roof in a hot climate must both reflect heat and insulate properly. The ideal walls must be shaded to reflect solar radiation, and insulate against the heat peaks during the day. In hot-arid regions, walls should allow storage of a certain amount of solar heat which then can radiate into the room during the night. It should

be noted that heat storage and capacitance are a liability in hot-humid climates and sunshading and ventilation techniques are most effective for creating comfort.

The majority of literature discussing the selection of building materials presupposes a professional's knowledge of their thermal and physical properties [2.1-2.5]. Nevertheless, sources 1.1 and 1.2 include tables, given in metric units, on the heat absorption, storage and insulating properties of most common building materials including their common structural usage. Efforts have been made to suggest which materials are best suited thermally and durability wise based upon the differences between hot-arid and hot-humid climates. Generally, for foundation materials, adobe is successful in hot-arid climates. Wood or light construction panels are well suited for hot-humid. Literature sources covering the selection and use of various materials are discussed in the "Building Materials and Methods" section of this chapter.

Shading and Solar Radiation Control

Solar radiation control is the simplest and most effective way to keep solar radiation heat out of building interiors. Because East and West walls gain most solar heat, these surfaces should be minimized in tropical climate areas. A second important strategy is to isolate or control the heat producing effects of cooking. One method of reducing radiant heat is by coloring exteriors with light pigments. The possible disadvantage of this measure though is an increase in glare but this can be controlled in most cases [1.1, 1.2, 1.3, 1.6, 3.5.]. Shading devices are the simplest means of controlling radiation heat gain and can be produced with local materials and methods. They can interfere with optimal air flow needed for ventilation in hot-humid climates so care must be exercised. Some examples of shading devices are:

- Horizontal Screening, Roof Overhang - These structures are effective against overhead sun especially if located on North and South facades.

- Vertical Screening - These elements best moderate against low sun such as that which strikes the West and East facades. Maximum efficiency is achieved when these devices are movable to promote ventilation.

- Mashrabias, Curtains, Shutters - Arabian mashrabias are traditional wooden trellis work which screens against sun as well as ambient glare. Shutters such as jalousies are also effective as well as curtains made of any flexible material such as cloth.

- Vegetation, Landscaping - Shading with trees or shrubs can be desirable with the added benefit of cooling oncoming air flow. Pergolas with creeping vegetation is also an effective sun screen. The major drawbacks to shading with vegetation are the control of insects and possibly obstructing desired ventilation if the vegetation is too dense, or placed too near wall openings.

Roof Design

An estimated 50% of energy inefficiency in buildings is caused by poor roof designs and roofing materials. Some measures that have been proven successful are detailed well in the National Academy of Sciences publication [2.3] and the Watson-Labs book [1.6], both replete with photos and diagrams.

- Roof Overhangs - The specific dimensions of roof overhang depend on a particular locale's angle of solar radiation. The material used should have insulating qualities.

- Ventilated Roof - This is a steeply sloped roof (made of reflective materials) positioned directly over a flat, insulated ceiling. The space under the roof is ventilated through wall openings to create a cool buffer zone between the roof and the ceiling. This design is only applicable to hot-humid climates.

- Icehouse Roof - This double, parallel plane roof construction includes an outer roof of shingles and sheathing on wood nailers, and an inner roof made of roofing felt and sheathing situated on rafters. A thermal chimney positioned at the top provides an exit for heat dissipation.

- Flat Roof - This form of roof must be ventilated due to its high absorption of radiant heat. It is not recommended for areas where heavy rains occur because of inadequate runoff and the incidence of structural damage.

- Roof Ponds - Roof ponds promote a comfortable interior climate beneath, due to heat reflection and absorption during the day and radiation of stored heat at night. This is known as night sky radiation. This type of roof device has structural limitations requiring 100% waterproofed seals and structural durability to carry heavy weight loads. This device is not applicable to the humid tropics because of low diurnal variation.

Ventilation

Designing for adequate ventilation is one of the best techniques for energy efficient, thermal comfort in hot-humid climates. The objective of ventilation is to stabilize indoor temperature at a lower level than the outdoor average diurnal temperature. The functional characteristics of wind behavior with respect to ventilation are its velocity, and direction of movement. Ventilation design elements serve to direct the air flow through a building by the size and placement of fenestrations (i.e., doors and windows) to regulate the intake and outtake of air for optimal ventilation. Specific guidelines for ventilation are explored thoroughly in references [1.1] and [1.6]:

- For Hot-Humid Regions

  .. Make the outlet openings larger than the inlets. This creates high velocity air flow in the interior necessary for cooling due to little difference in diurnal temperature.

  .. Open the building up to the prevailing breezes during the day and evening.

- For Hot-Arid Regions (ventilation is less important here)

  .. Make large openings of roughly the same size so that inlets face the prevailing nighttime summer

breezes and outlets are located on the side of the building directly opposite the inlets. This allows for cross-ventilation necessary for humidification (evaporative cooling).

.. Open the windows at night to ventilate the room and cool interior mass.

.. Close the building up during the daytime to keep the heat out.

Two related applications of ventilation discussed by Bowen, Konya and others are:

- Mobile Interior Construction - In Japan the custom of using movable wall slats can reduce the area of the room needing ventilation. Slats can also act to direct air flow in order to maximize cooling.

- Thermal Chimneys - These roof openings operate on the thermal principle that warm air rises and can get stacked under the roof unless a release opening is created. Thermal chimneys usually have overhangs placed on top of them which serve as an additional shading device.

A further point brought out well in reference 4.1 suggests that fenestrations must be designed with a dual purpose of making use of daylight needed for illuminating routine tasks without undue solar heat gain as well as to regulate and direct efficient air flow.

Humidification and Dehumidification

The last climate-conscious design consideration identified in the literature reviews cooling techniques through humidification (hot-arid), and de-humifidication (hot-humid) [1.1, 4.2 and others]:

- Humidification - In hot-arid regions, considerable physical comfort and cooling of room interiors can be realized by humidification or evaporative cooling techniques. The intent of humidification is to lower the apparent dry-bulb temperature. This technique promotes the lowest temperature attainable by evaporating water in to the air without increasing the energy content. Several humidification techniques are well presented diagramatically in the SKAT and International Passive Cooling Survey sources, which

illustrate how to coordinate cross-ventilation designs with humidifiers.

- Dehumidification In regions where the primary cause of heat retention and physical discomfort is high humidity, removal of moisture content in the atmosphere serves to reduce the wet-bulb temperature. The best way to control humidity is through induced ventilation and adequate air velocities. Calculating the necessary velocity of ventilation is covered in the Bowen, Watson-Labs, and Konya texts. Another method of natural cooling is by reducing humidity through the use of dessicants. Dessicants are inexpensive and re-usable salts which absorb humidity. The most common dessicants used are Silica Gel and Lithium Chloride ($LiCl_2$). Dessicants are still widely used in the humid Southeastern United States. Their main disadvantage is that dessicants reach a moisture saturation point and require a heat source for drying. Diachok and Shanks discuss the option of using a solar heat source as an energy conserving method of making dessicants renewable although this has not yet proven practical.

Building Materials and Methods

This is a crucial aspect of building for energy and resource conservation. The physical characteristics of a material and how it performs are major determinants of the viability of climate-conscious design. This is particularly evident in the misuse of galvanized iron for roofing throughout the world. Its thermal properties absorb and transmit a high degree of radiant heat rather than the desired reflection of heat energy [National Academy of Sciences, 2.3]. However, no literature source thus far adequately deals with the entire spectrum of building materials, their use, selection, applicability to climatic variation, and potential adoption in urban areas of developing nations. This area is well documented for industrial countries. The existing literature differentiates both materials and methods in a case-by-case approach, oftentimes presupposing that the user is a professional, already informed regarding its various strengths and weaknesses. Despite these limitations, the following literature sources are useful guides to various materials and low energy building methods:

- The National Academy of Sciences reference [2.1] on roofing in LDC's considers many potential materials, however, without the backup of methodologies or field applications. Even so it is still useful as an overview of promising technologies.

- References [2.1] and [2.3] evaluate bamboo as a renewable material that is inexpensive, easily repaired, well-ventilated, sturdy and earthquake resistant. Deterioration from insects and difficulting adapting this material to an urban setting are the chief drawbacks.

- Wolfskill's "how-to" [2.6] text on earth building goes well with Fathy's [3.2] more general discussion and experiences in Egypt with indigenous materials and methods. Wolfskill's manual covers many areas of earth masonry construction such as: different types of soils, testing soil, soil stabilizers, cements and preparing soil. Also covered extensively are the three methods of earth construction: adobe, rammed earth and pressed blocks. The materials and methods can be applied in many climates. A thorough discussion of various soil cements useful for earth construction in the humid tropics is particularly well presented.

- Ferrocement is a popular "new" building material. The reinforcement of cement, sand and water with flexible wire mesh makes the material extremely versatile [2.6]. Its use in Asia though tends to be limited to such non-shelter functions as food storage bins and boats due to its inability to "breathe." It has been used with success as a roofing material in several hot-arid countries in Africa.

- Timber construction according to Elliott [2.1] can be 20-30 percent less expensive to build because of savings in milling and frame construction. The material's durability against earthquakes and high winds is lauded as well as its use as a potentially renewable energy source. However, proper use of timber requires that wood preservation substances be applied and specifics of these processes are only cursorilly broached.

- Many communities have relied on their own ingenuity to utilize available local materials such as aggregates, thatching or swish-crete to construct dwellings. These "appropriate technology" approaches, unique to the particular resources of a community, have developed many useful building components applicable to other locales. [3.2., 4.2.]

CASE STUDY APPLICATIONS

Actual applications of energy and resource efficient building in LDCs have been fairly limited. Moreover, many building projects that have addressed energy issues remain unrecorded. Additionally, documented cases of energy-conscious designs and low technology building methods have not been evaluated after implementation for efficiency performance, time and labor requirements, and lastly, their acceptance within a community.

To date, published case studies of energy-efficient building design and materials primarily focus on climatic analysis, and passive solar concepts. The importance of utilizing the natural environment in building design cannot be overstated. Daylighting is also a natural energy source. One of the easiest methods to reduce the consumption of electricity generated to operate artificial lights and air conditioning dramatically is to design structures with solar control (shading) devices at windows that are oriented specifically for natural daylight and ventilation. The potential of daylighting applications for both commercial and residential urban structures is very promising. A recent example of designing with an emphasis upon daylighting and ventilation for energy efficiency in a commercial urb structure [4.1] was recently initiated in Manila, Philippines. Architects for the new headquarters of the Government Service Insurance Systems (GSIS) building have fashioned an excellent combination of orientation, sunshades, trellises, daylighting, ventilation and flowing water which make the most of energy found naturally in the environment. The energy problems and strategies utilized are outlined below:

- The Philippines imports nearly 90% of its fuel.
- Manila and other Philippine cities experience regular brown-outs and occasional blackouts.
- Undirected, intense sunlight on structures creates excessive heat gain and glare.

- Thermal consumption from air conditioning and artificial lighting averages 65,000, Btu/sq. ft./yr. for similar sized buildings (760,000 sq. ft.) in Manila.

- A hot-humid climate requires cooling as the major energy drain.

- The Architects Collaborative, Inc., the primary architects for the GSIS building, concentrated on designing a system of terraced "pods" which reinforce many energy saving strategies. The pods or clusters of the building structure will act as wind scoops to catch the prevailing Westerly winds for natural ventilation.

- Vegetation surrounding structural openings serves to cool oncoming breezes.

- A system of sunshades serves to direct certain angles of sunlight into the building to promote natural lighting into work areas. Other sunshades block sunlight that creates radiant heat gain and glare. Each facade of the structures has a different combination of sunshades depending on specific solar intensities.

- The "pods" are broken up to maximize workspaces near windows for natural daylight. Between pods are timber trellises, painted white and oriented North-South, to direct diffused daylight to workplaces while filtering heat gain sun rays lower than 45°.

- The building's angular slopes are part of an elaborate runoff system necessary to accommodate heavy seasonal rainfall.

The energy budget for this building is estimated to consume 30,000 Btu/sq. ft./year, which is less than half that of a similar sized building in Manila. This savings is a result of a marked decrease in reliance on mechanical systems. No mention was made regarding the selection of building materials or construction techniques, an area where greater energy and resources savings might have been realized.

A case study evaluation of traditional housing in Bhutan [4.3] discusses criteria for new housing design based upon traditional building solutions that are indigenous to a specific locale, climate and culture. Although this study doesn't

specifically discuss recent examples of implementing energy technologies in building, it does provide an excellent account of renewing an interest in indigenous designs, materials and methods integral to government planning of coordinated housing program initiatives. The range of elements considered in this study include:

- Land Use
- Building Design
- Existing Building Materials
- Building Products and Industries
- Administration

The criteria used to compare and evaluate recent buildings to vernacular architecture are as follows:

- Urban Density
- Urban Layout and Associated Cultural Values
- Urban Layout and Climatic Conditions
- Urban Layout and Topography
- Urban Layout and Air Circulation
- Traditional House Design
- Building Economics
- Health and Safety
- Climatic Adaptation
- Roof Structure
- Exterior Wall Structure
- Floors and Ceilings
- Finished Wood Trim[2]

Until the last decade, Bhutan widely practiced construction using traditional architecture. However, government-sponsored building programs have replaced the reliance on indigenous materials and styles to one largely dependent on imported materials and labor. As a result, buildings are appearing which are out of context with the climate, local resources, and the culture. These are significant variations of climate within Bhutan, from the lowland, hot-humid areas, to the upland, temperate and alpine regions. Traditional Bhutanese styles have taken these considerations into account when choosing indigenous building materials and designs. The materials, whether they are timber, compressed earth or thatch, have been chosen for their thermal properties as well as the efficient utilization of the country's scarce resources. Styles reflect climate conscious design forms as well. The study importantly cites a comparison of costs of building materials to labor input for "modern" one and two story houses. The ratio of these costs was estimated to be about 80%: 20%, materials to labor costs. Moreover, an estimated 64% of the total construction costs were derived from imported materials. The findings of this study indicated that the most effective starting point for housing initiatives in Bhutan is, at a minimum, stressing the use of traditional building materials and methods. Secondly, the materials themselves could benefit by innovations that promote durability and health safety, but these measures should not substantially change the economic and resource efficiencies gained by the use of indigenous materials and methods.

Watson's Passive Energy Principles for Housing in Mexico [4.4] gives, in a field guide format, an approach to climate and resource conscious housing design. Mexico's climate ranges greatly from warm-humid to hot-dry to temperate zones. The guide's objective is to illustrate the tools of climatic design that will provide comfortable conditions while making most efficient use of the available resources. The main consideration for most of Mexico's climatic zones requires the creation of comfort in overheated conditions. The suggested technique for shelter

employs passive cooling techniques. Results based on climatic analysis are as follows:

> "In climatic zones where the daily temperature swing ranges from warm days to cool or comfortable nights, time-lag effects can be combined with night ventilation.
>
> "If there is an annual temperature swing that includes moderate or cool winters, ground temperature heat exchange techniques might be exploited, such as through underground or earth-sheltered design.
>
> "In warm humid zones, the principal natural cooling technique is ventilation."[3]

The guide gives specific climatic profiles of different geograhical locations in Mexico and describes applicable design techniques in narrative detail.

Diachok and Shanks International Passive Cooling Survey [4.2] is a collection of case studies, both domestic and international, that have used climate-conscious analysis for the design and application of passive cooling building technologies. The case studies focus on highly technical discussions oriented to the professional. They are useful, though, in that the use of climatic analysis technologies already reviewed in this chapter are presented as the state-of-the-art. The neglected topics in this volume are the selection of building materials, time and labor requirements, and lastly, evaluations of energy and resource conservation applications.

GLOSSARY OF TERMS

Absorptance - the ratio of the radiation absorbed by a surface and the total energy falling on that surface measured as a percentage.

Active Solar Energy System - a system which requires the importation of energy from outside of the immediate environment; e.g., energy to operate mechanical devices such as fans or lights.

Adobe - a sun-dried, unburned brick of clay (earth) and straw used as a construction material.

Ambient Temperature - surrounding temperature, such as the temperature around a house.

Auxiliary System - a supplementary energy system that provides heat, cooling, or light to a space when its primary unit cannot do so. Sometimes also referred to as a "back-up system".

Berm - a man-made mound or hill of earth used in underground earth dwellings.

Btu (British thermal unit) - a unit used to measure the quantity of heat energy. Technically, a measure of the quantity of heat required to raise the temperature of one pound of water 1° F. One Btu = 252 calories.

Calorie - a unit of heat (metric measure); the quantity of heat equivalent to that needed to raise the temperature of one gram of water 1° C. One calorie is approximately equal to 4 Btu's.

Chaulking - making an airtight seal with a non-porous material, by filling in cracks around windows and doors.

Centigrade Degrees (C°) - a temperature scale consisting of or divided into 100 degrees. Centigrade temperatures are related to fahrenheit temperatures by the equation C = (F - 32) ÷ 1.8.

Chimney Effect - the tendency of air or gas to rise when heated owing to its lower density compared with that of the surrounding air or gas. This principle is used to help cool a building by allowing hot or warm air to rise out through upper level windows. This creates a negative pressure which draws cooler outdoor air in through windows at a lower level.

Clerestory - a window situated vertically in a wall above one's line of vision to provide natural daylighting to interiors.

Climate - the meteorological conditions including temperature, precipitation, humidity and wind that typically prevail in a particular region. Climate is not synonomous to weather.

Collector, Solar - a device for capturing solar energy, ranging from ordinary windows to complex mechanical devices.

Condensation - the accumulation of water droplets or frost, on the inside of a surface of a building when warm, mositure laden air from the interior reaches a point where temperature no longer permits the air to sustain the moisture it holds.

Conduction - the process by which heat energy is transferred through materials.

Conductivity - the quantity of heat (Btu's) which will flow through one square foot of material in one hour when there is a 1° F temperature difference between both sufaces.

Convection - the transfer of heat between a moving fluid medium (liquid or gas) and a surface, or the transfer of heat within a fluid by movements within the fluid.

Direct Gain - solar energy collected (as heat) in a building without special solar collection devices. Examples: through windows or absorbed by a roof or outside walls.

Diurnal Variation - the difference in temperature within a 24 hour period.

Dry Bulb Temperature - a measure of the sensible temperature of the air (the one which we are most familiar).

Energy - the capacity for doing work. Energy types are thermal (heat), mechanical (work), electrical and chemical.

Fahrenheit Degrees (F°) - a temperature scale which registers the change of state of water at a standard atmospheric pressure (liquid-gas-solid).

Fenestration - a term used to signify an opening in a building to admit light and/or air.

Glare - excessive daylight that may cause problems with vision due to the angle of light, contrasts between light and dark reflecting surfaces, and other vision related factors.

Insulation - materials or systems used to prevent the loss or gain of heat.

Nocturnal or Nighttime Cooling - the cooling of a building or heat storage device by the radiation of excess heat into the night sky.

Radiation - the direct transport of energy through space by means of electromagnetic waves.

Reflectance - the ratio or percentage of the amount of light reflected by a surface to the amount incident. The remainder that is not reflected is either absorbed by the material or transmitted through it. Good light reflectors are not necessarily good heat reflectors.

Retrofitting - installing energy saving heating, cooling or lighting systems in existing structures not originally designed for the purpose.

Roofpond System - an indirect gain heating and cooling system where the mass, which is water in plastic bags, is located on the roof of the space to be heated or cooled.

Sensible Heat - heat that results in temperature change.

Skylight - a clear or translucent panel positioned into a roof to admit sunlight.

Thermal Storage Wall - a masonry or water wall used to store heat from the sun during daylight hours. The stored heat is later emitted from the wall when the ambient temperature declines (time-lag cooling).

Time-lag - the period of time between the absorption of solar radiation by a material and its release into a space.

Weather - the state of the atmosphere at a given time and place.

Wet-bulb Temperature - the lowest temperature attainable by evaporating water into the air without changing the energy content.

LIST OF FOOTNOTES

1. Watson, D. "Energy Planning for Developing World Cities", p. 391.

2. Watson, D. "Indigenous Architecture as the Basis of House Design in Developing Countries: A Case Study Evaluation of Traditional Housing in Bhutan", pp. 209-210.

3. Watson, D., Passive Energy Principles for Housing in Mexico, p. 1.

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1.2. Evans, M., Housing, Climate and Comfort, the Architectural Press, London, 1980.

1.3. Konya, A., Design Primer for Hot Climates, Architectural Press, London, 1980.

1.4. Olgyay, V.V., Design with Climate, Princeton University Press, 1963.

1.5. Stulz, R., Elements of Solar Architecture for Tropical Regions, SKAT - Swiss Center for Appropriate Technology, St. Gall University, 1980.

1.6. Watson, D. and Labs, K., Climatic Design for Home Building, prepared for the NAHB Research Foundation and the U.S. Department HUD, 1980.

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2.3. National Academy of Sciences, Roofing in Developing Countries: Research for New Technologies, Washington, D.C., 1974.

2.4. United Nations Department of Economic and Social Affairs, The Use of Bamboo and Reeds in Building Construction, 1972.

2.5. Vietmeyer N.D., et al., eds., Ferrocement: A Versatile Construction Material: Its Increasing Use in Asia, Asian Institute of Technology, Bangkok, 1976.

2.6. Wolfskill, L., Handbook for Building Homes of Earth, U.S. Department of Housing and Urban Development, Washington, D.C., n.d.

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3.2. Fathy, H. Architecture for the Poor, University of Chicago Press, 1973.

3.3. Flavin, C., Energy and Architecture: The Solar and Conservation Potential, Worldwatch Institute, Washington, D.C., 1980.

3.4. Stokes, B., Global Housing Prospects: The Resource Constraints, Worldwatch Institute, 1981.

3.5. U.S. Department of Housing and Urban Development and U.S. Department of Energy, Regional Guidelines for Building Passive Energy Conserving Homes, 1980.

3.6. Watson, D., "Energy Planning for Developing World Cities: Opportunities in Integrated Approaches to Urban Infrastructure, Light - Industry, Commerce, and Building", Housing Science, Vol. 4, No. 5, 1980.

IV. Case Studies

4.1. The Architects Collaborative, Inc., "Terraced Pods Invite Daylight and Breezes", Architectural Record, Mid-August 1981.

4.2. Diachok, D. and Shanks, D., International Passive Cooling Survey, Solar Energy Research Institute, Golden, Colorado, 1980.

4.3. Watson, D. and Bertaud, A., "Indigenous Architecture as the Basis of House Design in Developing Countries; A Case Study Evaluation of Traditional Housing in Bhutan", HABITAT, Vol. 1, No. 3/4, 1976.

4.4. Passive Solar Energy for Housing in Mexico, A report for the Solar Energy Research Institute (SERI) International Programs, U.S. Department of Energy and the Republic of Mexico (SAHOP), 1980.

APPENDIX

ANNOTATED LIST OF REFERENCES AND ABSTRACTS

LAND-USE PLANNING

1. American Planning Association (Erley, Duncan, et al.), Energy-Efficient Land Use. Chicago, Illinois: Planning Advisory Service Report No. 311, 1979.

   This is one of a series of periodic reports the APA issues to its members on topics of general interest to planners. The report covers site design and microclimate; housing density, land-use integration, and transportation; and implementation (using case study examples). It also includes an annotated bibliography on energy audits and additional references. Valuable to the practitioner interested in specific energy-efficient planning tools.

2. Beier, George, et al., "The Task Ahead for the Cities of Developing Countries," World Development. Vol. 4, No. 5, May 1976, pp. 363-409.

   The primary objectives of this article (a World Bank reprint) are to examine the causes of rapid growth of urban areas in developing countries, differences among countries in their ability to manage this growth, and tools that can be utilized at the national and sub-national levels. The principal value of the article to planners is the typology of country experiences developed and a discussion of priorities for each type at the national level of greater value to national-level planners than to local practitioners.

3. Boyden, Stephen, An Integrative Ecological Approach to the Study of Human Settlements. Paris, France: United Nations Educational, Scientific, and Cultural Organization (UNESCO), Man and the Biosphere (MAB) Technical Notes 12, 1979.

   This monograph is part of a UNESCO-sponsored program on Man and the Biosphere (MAB) and adopts an ecological view of development. The conceptual model presented by the author includes a series of diagrams and checklists of value in obtaining an overview of developmental systems and interactions. Quite theoretical in nature.

4. Harwood, Corbin Crews, Using Land to Save Energy, Environmental Law Institute State and Local Energy Conservation Project, Cambridge, Mass.: Ballinger Publishing Co., 1971.

   Comprehensive review of land use planning as it relates to energy conservation published as a result of Environmental Law Institute State and Local Energy Conservation Project. Covers regulation, general planning, use of specific strategies (e.g., zoning, building codes), planning for new development, and energy impact statements in detail. Appendices also cover legal issues and selected legislation. For

each tool discussed, there is a presentation of legal issues, secondary impacts, and implementation. Excellent reference book for seasoned planner with a stress on legal issues; probably too detailed for the beginner.

5. Ridgeway, James, Energy-Efficient Community Planning. Emmaus, Pa.: The JG Press, Inc./The Elements, 1980.

A series of case studies covering several U.S. cities which have developed community-based strategies for energy conservation (e.g., Davis, Cal.). Also has brief sections on housing, solar energy, national energy planning, and a checklist for energy action. Excellent companion to studies dealing with planning standards and technical issues.

6. Rivkin, Malcolm, "Some Perspectives on Urban Land Use Regulation and Control," in Urban Land Policy Issues and Opportunities, Volume II. Washington, D.C.: The World Bank, Staff Working Paper No. 283, May 1978, pp. 85-126.

This is part of a broader World Bank publication which covers a series of topics associated with land (e.g., valuation, taxation, tenure). The section provides a comprehensive treatment of such issues as the rationale for land use planning and control, constraints, examples of interplay and impact, the specific techniques available, and policy issues. All topics are dealt with from the perspective of developing countries, and the author has prepared case studies in separate publications. Excellent companion piece to the APA monograph and/or Harwood for comprehensive coverage of general approaches, specific (technical) standards, and legal issues.

7. Rondonelli, Dennis and Kenneth Ruddle, Urbanization and Rural Development: A Spatial Policy for Equitable Growth. New York, N.Y.: Praeger Publishers, 1978.

A textbook-style publication which addresses urbanization issues in developing countries. Provides framework for integrated rural development and local project implementation, with a stress on provisions of local services and its relationship to land use. Also provides valuable table on methodologies and information required for integrated spatial development planning. Useful general reference for trained planner.

8. Urban Land Institute (ed.), Energy-Efficient Community Development Techniques: Five Large-Scale Case Study Projects from the U.S. Department of Energy's Site and Neighborhood Design (SAND) Program -- Phase I. Washington, D.C.: The ULI, 1981.

Another series of U.S. case studies reporting on an experimental Department of Energy Program. Useful listing of

techniques used in different projects and influence of such factors as climate and project design. Communities dealt with are generally planned extensively and developed privately, with a sub-area (e.g., 100 acres or more) designated for experimental conservation approaches. Although areas are generally high income and not analogous to developing countries, it might be possible to learn lessons from these experiments if some type of "demonstration site" is planned by a city.

9. World Bank, Renewable Energy Resources in Developing Countries, Washington, D.C.: The World Bank, 1981.

Provides a detailed review (including glossary of terms) of renewable energy alternatives in terms of the needs of developing countries and the role of the World Bank. Areas covered include fuelwood production, stoves, charcoal, biogas (cooking), solar drying, photovoltaics, windmills, small hydro (rural power technologies), alcohol, combustion and pyrolitic gasification of biomass, and solar water heaters (modern sector). World Bank is stressing fuelwood and alcohol production on a national scale, plus gaining operational experience and building local capacity for other types of renewable energy production.

TRANSPORTATION

A. GENERAL

1. Hammerton, S. K., R. J. Strickland and N. E. Weeks, "The Influence of Funding Agency Policies on Urban Project Design and Implementation", Transport Planning in Developing Countries, PTRC, July 1980.

   This paper traces the evolution of World Bank policies in the evolution of World Bank policies in the transportation sector through the 1960's and the 1970's, and examines current objectives, guiding principles and criteria used in the preparation of urban transport projects in developing countries. The influences of these policies on actual projects carried out are discussed, together with a broad indication of the types of practical difficulties experienced in the field by consultants carrying out the work. Finally, the paper comments on issues that have emerged from recent projects and offers suggestions for achieving a more successful outcome of transport projects in developing countries.

2. Koenigsberger, O. H., et al., Infrastructure Problems of Cities of Developing Countries, An International Urbanization Survey Report to the Ford Foundation, July 1971 (Section on Urban Transportation by Michael Tyler).

   Describes the problems facing urban systems in the major cities of the developing world with suggestions for further study.

3. Owen, Wilfred, Automobiles and Cities: Strategies for Developing Countries. Paris: Organization for Economic Cooperation and Development, 1973.

   An inquiry into the impact of the motor vehicle on the environment. The paper summarizes trends and outlooks and recommends improvements in urban transport through buses, traffic management, rail rapid transit, and reducing congestion by influencing demand.

4. Owen, Wilfred, Distance and Development: Transport and Communications in India, the Brookings Institution, Washington, D. C., 1968.

   Detailed study of transportation problems in India based on a 1965-66 study for the World Bank. Application of ideas made to other less-developed areas.

5. Roth, G., "Urban Transport Issues: A World Bank Approach", paper prepared in 1980.

The purpose of this paper is to sketch the World Bank's approach to urban transport problems, which is based on its commitment to alleviate urban poverty, and to describe some of the issues affecting its urban transport lending. Fundamental to the Bank's approach is the need to place the physical elements of urban transport projects in the context of institutional development and management solutions. The Bank seeks to support low-cost measures with quick payoffs. It is particularly concerned with physical and pricing methods to promote more efficient use of road space, and with regulatory reforms that encourage the provision of unsubsidized transport services responsive to travel needs of all income groups, especially at the lower levels.

6. World Bank, Urban Transport, Sector Policy Paper, May 1975.

Attempts to analyze the long-term implications of alternative urban transport strategies and investments in the context of accelerated urban growth in developing countries. Considers a five-year program for Bank involvement in projects supplementing basic transport systems directed toward the improvement of mass transit and goods traffic, and to the needs of cyclists and pedestrians who cannot afford even low-cost public transport.

7. Zahavi, Y., Travel Characteristics in Cities of Developing and Developed Countries, World Bank Staff Working Paper No. 230, March 1976.

The main purpose of this paper is to explore the systematic components of travel characteristics in cities of both developing and developed countries. The results may assist in the review of urban transport studies, in testing the consistency of forecasts and in discussions about alternative plans for urban form and transportation.

B. TRAFFIC MANAGEMENT

8. Dunford, J. E., J. S. Walker, and J. A. Cracknell, "Bangkok Traffic Management Project - Problems of Scheme Design and Implementation", Planning in Developing Countries, PTRC, July 1979.

A description of the problems encountered in implementing a series of traffic management measures in Bangkok. Many organizational problems were encountered in

attempting the many programs and political resistance required the abandonment of a number of them.

9. Holland, E. and P. Watson, "Traffic Restraint in Singapore," Traffic Engineering and Control. 19 (January 1978): 14-22.

Reports on the results of a project conducted by the World Bank to evaluate the effects of Singapore's traffic restraint scheme on the transportation system and the urban environment in the specific areas of traffic performance. Also investigates the potential for similar schemes for other cities.

10. Midgley, P., Urban Transport and Traffic Management: How to Maximize Benefits and Avoid Unnecessary Investments, paper prepared for the IRF IVth African Highway Conference, Nairobi, Kenya, 20-25 January 1980.

An analysis and compilation of traffic management measures currently in operation in European and North American Cities.

11. Midgley, P. and P. L. Watson, World Bank Experience with Urban Transport Projects: With Particular Reference to Latin America and Africa, paper presented to PTRC Summer 1981 conference.

The World Bank has financed projects in the urban transport sector since 1972 and over the past five years has developed several projects in Africa and Latin America with which the authors are especially familiar and which demonstrate well the approaches the World Bank has adopted in the sector. The first part of the paper concerns experiences in Latin America with specific reference to Brazil (Salvador de Bahia, Recife, Caritiba, Porto Allegre and Belo Horizonto). In the last part of the paper, the authors draw on their experiences with these projects to discuss urban transport issues confronting developing countries and the response of the World Bank.

12. Sato, K., Bikeways in Japan, pamphlet produced by the Japan Bicycle Road Development Association, Tokyo, Japan, n.d.

This report describes the bikeway construction program in Japan: physical design standards, functional classification, and the safety record.

13. Watson, P. L. and E. P. Holland, Relieving Traffic Congestion: The Singapore Area License Scheme, World Bank Staff Working Paper No. 281, June 1978.

This paper reports the results of the research program carried out by the World Bank to identify and measure the effects of Singapore's Area License Scheme on the transport system in particular and the urban system in general. The specific areas dealt with are: traffic performance, travel behavior, the business community, conditions for pedestrians, air pollution, and public opinion and attitudes. Under each category, the research methods are described and the results presented. In addition, the paper investigates the potential for developing similar license schemes for other cities and sets out the available options and variations, the decisions to be taken, and the prerequisites for successful implementation.

C. PUBLIC TRANSPORTATION

14. Case, D. J. and J. C. R. Latchford, A Comparison of Public Transport in Cities in South East Asia, TRRL Supplementary Report 659, Transport and Road Research Laboratory, 1981.

The transport of people in the cities of developing countries is undertaken by a large number of modes including walking, cycle, paratransit, bus, rail and car. It is the proliferation of the paratransit modes which has attracted considerable research interest but there is little known of the interdependence of all the travel modes. The term 'paratransit' describes a whole range of public transport modes between cycle and conventional bus. Past research in this field has either concentrated on a particular mode or on a particular urban area. In an attempt to broaden the base of the research and to determine the interdependence of the various forms of public transport this report considers the characteristics of eight cities in Southeast Asia and their public transport modes.

15. Feibel, C. and A. A. Walters, Ownership and Efficiency on Urban Buses, World Bank Staff Working Paper No. 371, February 1980.

Efficiency in urban bus operation depends on, among other things, the institutional form of the bus business. For certain cities in LDCs where there are parallel private and publicly owned operations, it is demonstrated that the costs of private provision are between 50 percent to 60 percent of those of publicly owned concerns. Additional evidence is adduced to show that the

quality of private bus services is not markedly inferior and usually superior to the public bus operation.

16. Fouracre, P. R., The Development of Public Transport in Curitiba, Brazil, TRRL Supplementary Report 197 UC, Transport and Road Research Laboratory, 1975.

This Report describes a visit made to Curitiba, Brazil in April 1974 to advise on a new public transport system. The Municipality is introducing a transport system designed to be an integral part of the urban development of Curitiba. The basis of the system is a number of bus-ways which radiate from the city center and which will carry frequent express buses. The envisaged transportation system is described together with the thinking behind its organization and the likely prospects for its future development.

17. Fouracre, P. R., Intermediate Public Transportation in Developing Countries, TRRL Laboratory Report 772, Transport and Road Research Laboratory, 1977.

This Report presents a survey of intermediate forms of urban public transport used throughout the developing world. The controversy surrounding intermediate public transport is discussed and the more important issues and problems are identified. Brief descriptions of some examples are also presented which illustrate how these transportation systems are organized and operated. The purpose of the report is to elucidate the significant role that intermediate public transport performs in the urban sector of developing countries. This provides the background to further research work being conducted by the Overseas Unit of the Transport and Road Research Laboratory into the efficiency of these various forms of transport.

18. Fouracre, P. R., and D.A.C. Maunder, Public Transport in Chieng Mai, Thailand, TRRL Supplementary Report 285, Transport and Road Research Laboratory, 1977.

This report surveys the operations and organization of the pubic transport system in Chieng Mai, Thailand's second city. The role of the shared taxi service is examined and comparison is made between this form of intermediate public transport and the competing bus service. The report illustrates, by example, how important intermediate public transport can be in a developing country.

19. Fouracre, P. R. and D.A.C. Maunder, Public Transport in Surabaya, Indonesia, TRRL Supplementary Report 370, Transport and Road Research Laboratory, 1974.

This report surveys the operations and organizations of the public transport system in Surabaya, the second city of Indonesia. The three main forms of public transport (cycle rickshaws, minibuses and conventional buses) are described and compared. The role of 'intermediate' public transport in Surabaya's transportation system is determined. This provides an example of the import position which intermediate public transport has in the transportation networks of many Third World cities.

20. Heraty, M. J., "Minibuses in Kingston, Jamaica", Transport Planning in Developing Countries, PTRC, July 1979.

The research study described in this paper is one of a series carried out of the Overseas Unit by the Transport and Road Research Laboratory in cities of the Third World, to investigate the role of intermediate public transport (paratransit) within the overall public transport system. The work in Kingston went rather further than previous studies in the series by including an in-depth interview program with low income urban families. The author was also fortunate to have access to a national houshold survey carried out by the Ministry of Public Utilities and Transport.

21. Intermediate Technology Transport, Ltd. Notes on Simple Transport in Some Developing Countries. Information Paper No. 2, ITDG Transport Panel. Intermediate Technology Transport, Ltd., London, England.

The report discusses intermediate transport in Papua New Guinea, the Philippines, China and India, and describes the simple vehicles, human powered, animal-powered and motorized, which are used in those countries. 22 photos of simple vehicles are included.

22. Lim, W.Y., "A Comparative Study of Public Transport in Principal Asian Cities", World Bank Draft Report, Urban Projects Division, September 1978.

This report evaluates and rates the public transit systems of Kuala Lumpur, Singapore, Jakarta, Bangkok, Manila, Hong Kong, Bombay, Madras, Calcutta, and Karachi. Also included in this statistical analysis are London, Washington, D.C., and San Jose, Costa Rica.

23. Meier, A.K., Intermediate Transport in Southeast Asian Cities: Three Case Studies. Information Paper No. 4 ITDG Transport Panel, Intermediate Technology Transport Ltd., London, England, 1977.

This report provides three case studies of intermediate transport technology in Asian cities (Penang, wartime Saigon, and Jakarta). The author records the very rapid changes in intermediate forms of transport that have taken place in these cities, gives an account of the factors which have influenced this, and compares the three experienced.

24. Mitsui Consultants Co., "The Philippines," in Public Transport Requirements in Intermediate Size Cities. Tokyo: The Company, 1977.

Investigates and identifies the urban transportation problems centering around public transportation services specifically in Davao and Cebu. Gives a profile and discusses the urban development, highway and street systems' traffic condition and public transportation services of the two industrial cities.

25. Roth, G.J., "Regulation of Buses in Cities", Highway Research Record 476, 1973.

This paper examines the main types of regulations - control of routes, rates, timetables, and standards - applied to the provision of bus services in cities and considers their effects in the light of the requirements of travelers. Conclusions are that controlling standards of saftey, noise, and fumes to avoid the infliction of excessive costs on the public is generally desirable; regulating timetables, possibly in the form of subsidies to operators who keep to them, may have merit; controlling route operation and fares may not serve a useful purpose; and restrictions on the introduction of new bus services are not logical. The paper also discusses the case for bus subsidies and concludes that the need for subsidies does not justify the public operation or economic regulation of bus service. Grants related to passenger mileage on all or selected routes appear to be the most desirable form of subsidy, for they directly encourage the provision of services desired by travelers.

26. Walters, A.A., Costs and Scale of Bus Services, World Bank Staff Working Paper No. 325, April 1979.

This paper challenges the conventional wisdom that large buses in large organizations with subsidies to produce optimum frequencies are the best arrangement for urban road passenger transport. It is shown that in

theory small buses are often appropriate, giving the best frequencies and speeds and suitably low average passenger waiting times. Direct observations of minibus services in a number of cities tentatively demonstrate the veracity of the theory. Furthermore the best institutional organization is not the large firm or municipal authority, but the small firm, often the owner/driver. There is no case for any substantial subsidy for appropriately organized urban bus transport.

D. LABOR INTENSIVE METHODS

27. Allal M. and G.A. Edmonds, Manual on the Planning of Labor Intensive Road Construction, ILO, Geneva, Switzerland, 1977.

    A detailed manual on the planning, implementation and evaluation of road construction by various labor-intensive and semi-mechanized methods. Alternative technologies are described. Considerable emphasis is on hard project evaluation so as to determine the true economic cost of using various resources. Other organizational, contractual, financial, and managerial aspects are also covered.

28. California University, Institute of Transportation and Traffic Engineering, Opportunities for Cost Reduction in the Design of Transport Facilities for Developing Regions, prepared for the U.S. Department of Transportation Office of International Cooperation, Contract No. 10B.

    Considers problem of selecting low cost technologies applicable to developing countries: conditions of low facility utilization, low equipment usage, low unskilled labor costs, higher cost of capital and equipment, and scarcity of professional, technical and managerial skill, as contrasted with highly developed industrial economies.

29. Faiz, A. and E. Staffini, Engineering Economics of the Maintenance of Earth and Gravel Roads, Transportation Research Record No. 702, TRB, August 1979.

    This paper presents a methodology for the economic evaluation of maintenance programs for unpaved roads with low traffic volumes (under 250 vpd), a situation commonly encountered in rural areas in developing countries. The technique, drawing heavily on the road deterioration and user cost relationships developed in the IBRD/TRRL Kenya Road Transport Cost Study, involves a dynamic model that related vehicle operating costs to traffic-induced road deterioration.

30. Edmunds, G.A., "Appropriate Technology in Road Construction", Transport Planning in Developing Countries, PTRC, July 1975.

Based on cost analyses of four studies in Iran, Thailand, Nepal and the Philippines, this report argues that much of rural road construction could be based on labor-intensive methods using animal-drawn vehicles. Costs specific to the Philippines are cited.

31. Harral, C.E., et al., Study of the Substitution of Labor and Equipment in Civil Construction: Phase II Final Report, World Bank Staff Working Paper No. 172, 1974.

Continuing study based on research in several countries with labor-abundant economies, to establish the technical feasibility of alternative technologies involving different combinations of labor and equipment, and to determine the economically optimum technique in any given case by relating possible solutions in factor prices. Volume I: Main Report (overview and summary). Volume II: Collection and Analysis of Productivity Data (basic data and estimating equations derived). Volume III: Field Procedures for Data Collection (field manual).

32. Hide, H. and D. Keith, Effect of Simpler Road Improvement Measures on Vehicle Operation Costs in the Eastern Caribbean, TRRL Supplementary Report 527, Transport and Road Research Laboratory, 1979.

This report describes the effect on vehicle operating costs of a simple labor-intensive method of rehabilitating and maintaining badly deteriorated bitumen surfaced roads in the Eastern Caribbean. The techniques developed for the rehabilitation and maintenance of the roads are described, and the equipment, materials and manpower required are listed.

The rehabilitation and maintenance system is a simple one restricted to providing adequate drainage, filling the potholes in the road and providing a minimum seal over the whole road surface. The reduction in vehicle operating costs resulting from the improvement in the riding quality of the road surface is shown to be sufficient to recover the rehabilitation costs in a very short time even at flows as low as 100 vehicles per day.

33. Lal, D., Men or Machines: A Philippine Case Study of Labour/Capital Substitution in Road Construction, International Labor Organization, Geneva, forthcoming.

This book compares labor-intensive methods with capital-intensive methods for the construction of gravel-surfaced roads, and concrete-paved roads. Findings show that for gravel roads, the labor-intensive method compares very favorably at both market and shadow prices. With concrete slabs, however, the labor-intensive method is preferable only when a low shadow wage and a high shadow rate for renting equipment are assumed. It is estimated that if the labor-intensive methods are used throughout, 70 to 100 percent more jobs would be created than if the capital-intensive methods are used.

E. ACCIDENTS

34. Hills, B.L. and G.D. Jacobs, "The Application of Road Safety Countermeasures in Developing Countries", Transport Planning in Developing Countries, PTRC, July 1980.

This report examines the effectiveness of safety measures (signals and signing) in developing countries. It concludes that predictions of accident reduction are highly uncertain due to major differences in road user attitudes.

35. Jacobs, G.D. and P.R. Fouraor, Further Research on Road Accident Rates in Developing Countries, TRRL Supplementary Report 270, Transport and Road Research Laboratory, 1977.

Using published data, a study was made of changes in road accident rates over the ten year period 1961-71 in a number of developing countries. It was found that in the majority of countries there was a continuing downward trend in fatality and injury rates per licensed vehicle.

36. Jacobs, G.D. and P. Hutchison, A Study of Accident Rates in Developing Countries, TRRL Laboratory Report 546, Transport and Road Research Laboratory, 1973.

Using published data a study was made of changes in accident rates over time in a number of developing countries and it was found that, in almost all the countries, there is a continuing downward trend in fatality and injury rates per vehicle, Kenya and Zambia being notable exceptions.

Fatality rates were found to be related to vehicle ownership levels: the lower the vehicle ownership level, the higher the fatality rate per vehicle. In this relationship, vehicle ownership can be taken as an indication of both general economic and transport development. Fatality rates for the developing countries for the year 1968 were found to be similar in pattern to those for Britain between 1909 and 1938.

37. Jacobs, G.D. and I.A. Sayer, A Study of Road Accidents in Selected Urban Areas in Developing Countries, TRRL Laboratory Report 775, Transport and Road Research Laboratory, 1977.

This report presents an analysis of personal injury accident rates taking place on roads in selected urban areas in developing countries. It shows, for a number of cities, the distribution of accidents by type of road, class of road-user and vehicle involved.

It was found in the cities studied that the accident and casualty rates (per licensed vehicle) were about 60 percent greater than in urban areas in Great Britain. The fatality rates were found to be at least eight times greater than in Great Britain and up to thirty times greater than in the United States.

39. Jacobs, G.D., I.A. Sayer and A.J. Downing, A Preliminary Study of Road-User Behavior in Developing Countries, TRRL Supplementary Report 646, Transport and Road Research Laboratory, 1981.

This report describes the results of studies into the behavior of drivers and pedestrians in selected cities in developing countries. During the period 1975-1979 measurements of road-user behavior at traffic signals and uncontrolled pedestrian crossings were made in Cyprus, Kenya, Indonesia, Thailand, Turkey, Pakistan, Sri Lanka and Jamaica. In Kenya and Indonesia measurements were also made at priority junctions of the gaps accepted by motorists joining the major road. Wherever possible, results from these studies have been compared with similar studies carried out in Great Britain.

F. PLANNING

39. Adler, Hans A., "Sector and Project Planning in Transportation", World Bank Staff Occasional Papers, No. 4. The Johns Hopkins University Press, 1967, 3rd printing, 1973.

Presents basic steps in methodology and economic evaluation of transportation projects, emphasizing the need to deal not only with new investments, but with measures to make the optimum use of existing ones.

40. Banjo, G.C.A., "The Relevance of Travel Time Evaluation in the Developing Countries: Some Evidence from Nigeria", Transport Planning in Developing Countries, PTRC, July 1979.

This paper concludes, from theoretical and empirical considerations in Nigeria, that travel time values should not be equated to wage rates, that personal evaluations do not appear correlated to income, and that a single value should be used for the society as a whole.

41. Calogero, V., "Microcomputer Systems for Planning: User Considerations for Developing and Developed Countries", Urban and Regional Planning in Developing Countries, PTRC, July 1980.

This paper describes a transport investment planning information system which has been implemented on a small microcomputer and argues that such programs can potentially be cost effective.

42. Crouch, F.O. and D.T. Silcock, "Training in Transport Engineering for Third world Professionals: Lip-Service or a Real Service?", Transport Planning in Developing Countries, PTRC, July 1980.

This paper examines and utilizes four generic classes of transport training for developing countries: formal degree programs in developed countries, short courses in professional development, on-the-job training, and sponsored research.

43. Howe, J.G.D.F., The Sensitivity to Traffic Estimates of Road Planning in Developing Countries, TRRL Laboratory Report 516, Transport and Road Research Laboratory, 1973.

This report gives an analysis of the sensitivity to traffic estimates of rural road planning decisions in developing countries. Consideration was given to decisions concerning the annual amounts spent on maintaining

each section of road, the economic justification of road improvements, and the selection of road design standards and hence construction costs. The report shows how each of these decisions is sensitive to the traffic parameters used in making them. Many of the traffic parameters are shown to be subject to large errors due to the estimating methods currently in use. This is particularly the case with estimates of induced traffic likely to result from road improvements and the forecasts made of all future traffic for planning and designing road improvements.

44. Kogan, J.H., "Training Programme on Transport in Argentina", Transport Planning in Developing Countries, PTRC, July 1980.

This paper describes a successful 6-month training program in transport planning organized by the Direccion Nacional de Planeamiento and developed with the advice of the Economic Development Institute of the World Bank. Lecture material was integrated with the actual preparation of a national transport plan.

45. Schuster, H., "Transportation Planning Techniques: Problems and Prospects", Kyklos XXVII, 1974.

Assesses recent developments in transport planning techniques, including traffic forecasting methods, adaptation to changing requirements, the locational impact of changes in the transport system on other sectors of the economy, and the possible use of transport policy for influencing the regional pattern of economic and social activities, with suggestions for further research.

46. Shambesh, A. and P.J.B. Brown, "Data Collection in Developing Countries: Problems and Pitfalls of Survey Organization and Management", Transport Planning in Developing Countries, PTRC, July 1980.

This paper highlights some of the difficulties and problems encountered in data collection exercises in developing countries.

47. Thomson, I., "The Biasing of Transportation Planning in Latin America in Favor of Investment for the Benefit of Higher Income Citizens: An Introductory Investigation", Transport Planning in Developing Countries, PTRC, July 1980.

This paper examines a number of the sectors of urban transport planning models which bias the results in the direction of capital-intensive infrastructure investments which tend to benefit the rich.

48. Willumsen, L.G., "Appropriate Transport Planning Techniques for Developing Countries", Transport Research for Social and Economic Progress, Proceedings of the World Conference on Transport Research, London, April 14-17, 1980.

Describes some simple mathematical modeling techniques which the author believes are appropriate to transport planning in developing countries.

ENERGY AND ELECTRIC POWER

1. Brown, H. and K.R. Smith, "Energy for the People of Asia and the Pacific, "Annual Review of Energy Volume 5, J.M. Hollander, Editor. Annual Reviews Inc., 1980.

   This volume reviews topics germane to energy technology, including environmental, political, sociological, and economic aspects. Of special interest are two reviews of the energy situation in developing countries. One explores the potential renewable energy resources in developing countries, while the second examines the energy problems for the people of Asia and the Pacific.

2. Cecelski, E., J. Dunkerley and W. Ramsay, Household Energy and the Poor in the Third World. Washington, D.C.: Resources for the Future, Research Paper R-15, 1979.

   As a general introduction to issues in energy analysis and the poor, the monograph is an important state-of-the-art benchmark. That description is further justified by a long and useful bibliography.

3. Exxon Corporation, World Bank Outlook. December 1980.

   This annual report prepared by Exxon presents its projections of the supply of and demand for commercial energy resources, specifically oil, gas, coal, and nuclear resources. Projections are forecast through the year 2000 and include data for both the developing and industrialized world. In addition, the report also touches on the outlook for synthetic fossil fuels (e.g., shale oil, coal gases, etc.) and very heavy oil, i.e., oil whose primary production requires the use of heat or mining.

4. Fallen-Bailey, D.G. and T.A. Byer, Energy Options and Policy Issues in Developing Countries. World Bank Paper No. 350, August 1979.

   A background study for World Development Report, 1979. Reviews the energy resources of developing countries, with particular emphasis on those which import oil. Discusses the nature of these resources, the cost of developing them, and the policy issues raised in doing so. Also reviews issues related to power generation and fuel substitution and their costs.

5. Munasinghe, M., Electric Power Pricing Policy, World Bank Paper No. 340, July 1979.

   Reviews the basic theory of marginal cost pricing applicable to the power sector in developing countries and

summarizes the state-of-the-art. Explicit models are presented which permit modifications to be made to the strict long-run marginal costs for economic second-best reasons, and social/subsidized prices for the poor. Also discusses the tailoring of tariff policy to meet the financial needs of the sector and requirements such as simplicity of metering and billing. Paper presented at the LDC Energy Management Training Seminar, State University of New York - Brookhaven National Laboratory, Stony Brook, New York, November 1978.

6. National Academy of Sciences, Energy for Rural Development: Renewable Resources and Alternative Technologies for Developing Countries. Washington, D.C., March 1980.

This book presents a series of summaries for a variety of solar-related energy technologies as well as detailed technical descriptions of specific solar energy conversion systems. The technologies are discussed from the standpoint of applications in the near-term (within 5 years) and in the intermediate-term (within 5 to 10 years). The technologies that are described are of a decentralized nature and include both indirect uses (e.g., wind energy, geothermal, hydropower) and direct uses (e.g., heating, crop drying, photovoltaic electric power generation) of solar energy.

7. United Nations Commission on Human Settlements, Energy Requirements and Conservation in Human Settlements: Report of the Executive Director, March 1980.

This report presents the results of a discussion held on the topic "Energy Requirements and Conservation in Human Settlements" by the Commission on Human Settlements in Mexico City during May 6-15, 1980. Covered in the report are the salient energy issues that are related to human settlements in developing countries, including patterns of energy consumption by consuming sector, sources of energy, efficiency of energy conversion and utilization, policy matters related to solving energy problems, and the development of energy management plans.

8. World Bank, Energy in the Developing Countries. August 1980.

The sharp rise in the cost of energy in recent years has underlined the urgent need to expand domestic energy production in developing countries that are dependent on imports. In 1980, they will spend almost US$50 billion on importing oil. If their domestic energy production continues to grow no faster than in recent years (about 7 percent annually), their oil import bill (in constant 1980 US dollars) would rise by 1990 to $110 billion, a level which would add greatly to the difficulty of financing an already large external deficit. Although the increase in the real price of oil has put considerable strain on the balance of payments of the oil importing developing countries, it has also provided them

with ample opportunities to tap energy reserves of oil, gas, coal, hydroelectric and forest resources that were previously regarded as uneconomical, or of marginal value. By maximizing energy production between now and the end of the decade and by a vigorous program of energy conservation, the World Bank estimates that these countries could cut their oil import bill in 1980 by $25-30 billion (1980 dollars). If these developing countries are to achieve this substantial saving, they will need to take effective measures to encourage transportation, industry, and households to consume less and conserve more. Measures outlined in this paper show it is possible to save about 15 percent of the energy needed in 1990, without have to reduce overall economic growth. It is also imperative that all countries, industrialized and industrializing, adjust their domestic energy prices, incentives, and investment priorities to place more emphasis than at present on domestic production.

9. World Bank, Renewable Energy Resources in the Developing Countries. January 1981.

Renewable energy resources occur in nature, in the form of energy flows of indefinite duration, as opposed to mineral deposits of indefinite amount. Thus solar and wind energy, hydroelectric power and fuels of vegetable origin are regarded as renewables while mineral fuels are not. Many of the technologies for exploiting renewable energy resources rely on scientific and engineering principles that have been understood for decades, if not centuries. But, in addition, recent advances in such fields as electronics and synthetic materials have opened up a variety of new approaches to the solution of old problems. The recent growth of interest in the exploration of renewable energy resources in developing countries has been promoted by two main factors: the increased international price of oil and gas, and the alarmingly rapid depletion of fuelwood supplies in these countries. By now most developing countries have renewable energy programs of some sort underway. Many of these are research and testing activities conducted on a small scale, ad hoc basis, often under university or foundation auspices. Several countries, such as Brazil, India, and the Philippines, have larger and more systematic programs. This paper examines the contributions that renewable resources can make to energy supplies in developing countries, and discusses the rate of the World Bank in renewable energy devlopment over the next five years. This paper does not cover large-scale hydroelectric power, or geothermal power, since they involve "conventional" technology with a well established role in national electric power systems and in normal Bank operations. In order to concentrate on technologies of near- and medium-term interest to the largest number of countries, wave, ocean thermal and tidal power are not specifically referred to; neither are the prospects for increasing the

supply of animal power, or for using human and animal power more efficiently.

WATER AND SEWER

1. Carruthers, I.D., Impact and Economics of Community Water Supply: A Study of Rural Watch Investment in Kenya, Agrarian Development Series, Report No. 6, Wye College, Ashford, Kent, England, 1973.

   This report documents and discusses problems related to rural water development in Kenya. It is the specific objective of this study to integrate the various technical, engineering, agricultural and medical aspects of this investment process using an economists approach. The study further examines the rationale of the Kenyan development strategy, assesses the evidence supporting the premises, and appraises the means being adopted to achieve the program objectives. Recommendations are presented on ways to improve the cost-effectiveness of the investment.

2. Chamberlin, C.E., John Boland, Arunpel Malik and Harold Shipman, Wholesale and Palatable Drinking Water Supply, contained in Water: A Background Paper on Water Quality Aspects of Water Supply. A Panel Report to U.S. A.I.D., Washington, D.C., July 31, 1979.

   The purpose of this report is to provide background discussions of water quality aspects of water supply. Emphasizing small domestic water supplies serving dispersed rural populations in developing countries. This work was conducted for an expert panel developing water quality guidelines for the U.S. A.I.D. activities related to the World Water Supply and Sanitation Decade. The report primarily addresses questions of water quality influences on water-borne disease.

3. Elmendorf, Mary, "Women, Water and the Decade", Paper presented at the International Affairs Session, 1981 Centennial Conference, American Water Works Association, June 9, 1981.

   This paper provides an argument for water project implementation to look beyond technology to the roles and attitudes of the people who are expected to utilize new water and sanitation facilities. In particular, focus is on women, who are the primary users of water and socializers of their children and families in matters of personal hygiene. The lack of positive impact of past programs is primarily attributable to non-use and misuse of new facilities, not necessarily to the engineering aspects. Until women are involved and understand the importance of improvements, limited acceptance will result.

4. Feachem, Richard G., M. McGarry and Duncan Mara, Water, Wastes, and Health in Hot Climates, Wiley and Sons, 1977.

Alternatives to the conventional sewerage systems are discussed including: latrines, compact toilets, aqua-privy, night-soil cartage systems. In addition, a range of technical considerations are presented for water delivery, appropriate sanitation technologies, and the impact of health in tropical countries.

5. Kalberwatten, J.M., DeAnne S. Julius, D. Duncan Mara and Charles G. Gunnerson, Appropriate Technology for Water Supply and Sanitation, Volumes 1 and 2.

Volume one of this two volume set reports technical, economic, health and social findings of Research Project RPO 671-46, "Appropriate Technology for Water Supply and Waste Disposal in Developing Countries". The report discusses the program planning necessary to implement technologies available to provide socially and environmentally acceptable low cost water supply and waste disposal. Volume two of this report provides information and instructions on how to design and implement appropriate technology projects based on the findings reported in volume one. It provides guidelines and design tools to the engineers and sanitarians responsible for planning and implementing sanitation projects.

6. Republic of Terrania: A Case Study on the Economic and Financial Aspects of Programmes and Projects in the Drinking Water Supply and Sanitation Sector, World Health Organization/World Bank Cooperative Programme, 1980.

The Terrania Case Study was prepared in connection with economic and financial workshops organized by WHO/AFRO and the WHO/World Bank Cooperative Programme in the context of preparatory activities for the International Drinking Water Supply and Sanitation Decade. This study relates the present situation in Terrania in the context of a rural sub-sector development program of covering several water districts and discusses the development of a national plan and the preparation of a project plan with an emphasis on financial analysis and economic justification. It then discusses methods of relating the problems to methods for solution, and finally, provides guidelines for resolving the problems identified. Rather than dealing directly with the problems, an alternative approach is provided, entirely based on an institutional re-arrangement, which should prove to lead to the optimum solution.

7. Rybcznyski, W.C., Polprasert, and M.G. McGarry, Low-Cost Technology Options for Sanitation: A State-of-the-Art Review and Annotated Bibliography, International Development Research Centre for the World Bank: IDRC 102e/ Appropriate Technology for Water Supply and Sanitation, Vol. 4, Ottawa, Canada, 1978.

This comprehensive technology review and bibliography describes alternative approaches to collection, treatment, reuse and disposal of wastes. It is designed to describe to the policy maker, the administrator and the engineer the broad range of approaches to human wastes management available today. This document was prepared by the International Development Research Centre (IDRC) Ottawa, in cooperation with the World Bank.

8. Saunders, Robert J. and J.J. Warford, Village Water Supply, Economics and Policy in the Developing World, World Bank Publication, The Johns Hopkins University Press, Baltimore, Maryland, 1976.

This book focuses on the special problems that must be overcome if rapid improvement in basic water supply and sanitation to less privileged members of society is to be achieved. This study emphasizes the economic, social, financial and administrative issues characteristic of village water supply and sanitation programs. In addition, it presents recommendations that are directed to the special circumstances of rural communities and that are relevant to provision of adequate water and supply and sanitation facilities to the poor in urban areas of developing countries. The findings and recommendations are based on a detailed survey of relevant literature, personal observation of village water supply operations and sanitation programs, and accumulated experience of the authors and colleagues.

9. Sundaresan, B.B., "Water Supply and Sanitation Options in Developing Countries - A Case Study (India) in Project Monitoring and Reappraisal in the International Drinking Water Supply and Sanitation Decade. American Society of Civil Engineers 1981 International Convention and Exhibit, Charles G. Gunnerson and John M. Kalbermatten, eds., May 1981.

Technology adopted in developed countries in water supply and sanitation programs has limited application in developing countries. Engineering design overlooking social customs, cultural traditions and economic levels of community would prove ineffective. Community involvement and health education are as important, if not more, as technology aspects. One unit process - filtration - has been evaluated with specific reference to slow sand filter (SSF) and rapid sand filter (RSF) for conditions prevailing in India. SSF appears to be better suited in view of low capitalized cost

up to 23 million liters per day (mld) capacity, capability to withstand low operating skills and produce water of satisfactory quality. Successful implementation of a village demonstration project with SSF incorporating community involvement and health education is discussed. Integrated water supply and sanitation programs in urban squatter settlements as well as small towns have become necessary to maximize benefits to the community.

10. Water For All, Statement of the International Institute for Environment and Development, Symposium on Water, in preparation for the United Nations Water Conference, March 14, 1977.

A statement on behalf of the International Institute for Environment and Development Symposium on Water addresses issues considered by the Water Conference which deserve the highest priority of governments, international organizations and people all over the world. It is considered an appeal to political leaders on water supply and sanitation in the world countries and conservation and management of water resources.

11. White G.F., D.J. Bradley and A.U. White, Drawers of Water, University of Chicago Press, Chicago, Ill., 1972, p. 306.

Water supply improvements in the developing world have not kept up with population growth, especially in urban areas. To achieve maximum benefit from the expenditures made to remedy this gap, water projects must be based on greater knowledge of how water is used in the community, and how water improvements affect economic growth and community development and health. The conclusion drawn from this case study in East Africa is that, with both supply and disposal of water, once a minimum service is provided, the unit gain to health from units of improvement probably decreases sharply. Preliminary evidence, as indicated in this book, suggests that slow development of ideal "Western type" water systems should be set aside in favor of more rapid delivery of smaller quantities of potable water to every household.

12. Wilson, J.G., Pit Latrines in Botswana, International Development Research Centre, Proceedings of a Workshop on Training Held in Lobatse, Botswana, August 1980.

This is a brief discussion of the technical and sociological problems that have been associated with the introduction of sanitation programs in Botswana. It was not written to detract from the overall success that the government of Botswana has had in its implementation of such programs but rather to create an awareness of potential problems that could act as a base from which discussion could be generated with respect to the need for appropriately trained labor within the sanitation sector.

SOLID WASTE MANAGEMENT

1. Blide, A.D., et al., "Studies on Refuse in Indian Cities, Part II: Variation in Quality and Quantity," Indian Journal of Environmental Health, Vol. 17, No. 3, 1975.

   This report presents a country-wide survey of refuse composition in India measuring quality and quantity of refuse including compostable potential of its intricut value. In addition, the cost of services to collect and dispose of municipal budgets is reported.

2. Bhoyar, R.V., et al., "Intestinal Parasites in City Refuse," Vol. 15, No., 1978.

   This study on parasites in urban refuse from twelve Indian cities revealed two commonly found parasites - A. Lumbricoides and T. Trichiura. These were found to be particularly high in samples from refuse in slums and low-income neighborhoods, probably because of the inadequacies of available sanitation facilities. In addition, the highest incidence of parasites was found to be during the monsoon season.

3. Carruthers, I.D., Impact and Economics of Community Water Supply: A Study of Rural Water Investment in Kenya, School of Rural Economics and Related Studies, Wye College, Kent, Great Britain, Agrarian Development Studies Report, No. 6, 1973.

   This report documents and discusses problems related to rural water development in Kenya. It is the specific objective of this study to integrate the various technical, engineering, agricultural and medical aspects of this investment process using an economists approach. The study further examines the rationale of the Kenyan development strategy, assesses the evidence supporting the premises, and appraises the means being adopted to achieve the program objectives. Recommendations are presented on ways to improve the cost-effectiveness of the investment.

4. Cecelski, E.J., J. Dunkerley and W. Ramsey, Household Energy and the Poor in The Third World, Research Paper R-15, Published by Resources For the Future, Washington, D.C., 1978.

   The evaluation of the economics of small-scale biogas plants in India emphasizes that the benefits of this scale of biogas production are available only to a small percentage of upper class households, comprising a very small percentage of the population. It goes on to indicate that community cooperation in such projects is determined to a large extent by social factors such as the caste system and social customers. The waste system in particular is discussed.

5. Cointreau, Sandra J., Environmental Management of Urban Wastes in Developing Countries (Draft), The World Bank, Washington, D.C., August 17, 1981.

This report is an effort to develop a project guide for managing urban refuse in developing countries. The report is designed to identify the nature of managing municipal refuse regarding the public sector's responsibility to its citizens by protecting public health and safeguarding environmental quality. The report also presents a definition of urban refuse - its composition, generation rate, density and character. It further discusses problems and issues requiring consideration while developing a solid waste project and options in appropriate technology for developing countries' urban areas. Finally, institutional and financial arrangements are addressed.

6. Dickey, Christopher, "Burning Refuse Dump Chokes Mexico City, Rouses Ragpicker's Ire", The Washington Post, April 12, 1981.

A Washington Post newspaper article discussing the intricate social operations of a Mexico City waste disposal site. The article chronicles the operations of municipal workers selecting the most valuable refuse prior to disposing of it at the dump, and the assessment of fees for scavengers.

7. Feachem, R.G., D.J. Bradley, H. Carelick, and D.C. Mara, Health Aspects of Exreta and Wastewater Management, The World Bank, Washington, D.C., October 1978.

Public health is of central importance in the design and implementation of improved excreta disposal projects. Improvements in health are the main social and economic benefit which planners and economists hope to achieve by investing in excreta disposal. It is therefore necessary to make available as much information as possible about the interaction between excreta and health in order that engineers and planners may make informed and rational decisions. The information that is required not only concerns the broad epidemiological issues of the impact on disease of improvements in excreta disposal, but also the ways in which particular excreta disposal and reuse technologies affect the survival and dissemination of particular pathogens.

This book sets out to provide such information. It is intended for planners, engineers, economists and health workers and has been written with a minimum of jargon so that it can be readily absorbed by people from differing professional backgrounds.

This books has two parts. Part 1 presents a distillation of available knowledge on excreta, night soil, sewage and health. The emphasis is on presenting the complex, and sometimes contradictory, evidence as clearly and concisely as possible.

Part 2 contains a short account of each excreta-related infection, stressing the appropriate control methods and the role of an improved excreta disposal campaign. Emphasis is also given to the survival of the pathogen outside its host in order that the effect of various waste treatment processes may be clarified.

8. Flintoff, F., Management of Solid Wastes in Developing Countries, World Health Organization, New Delhi, Regional Publications, South-East Asia Series No. 1, 1976.

This paper examines existing waste disposal sector conditions, reviews techniques and methods available to overcome technical, institutional, social, manpower, and financial constraints and recommends actions which would help developing countries overcome these constraints at least cost.

9. Flintoff, Frank, Solid Waste Management in Cairo and Alexandria. The World Bank, 1978.

Discussion of a range of solid waste management issues including urban refuse generation rates in Cairo and Alexandria, costs of providing services to the cities, assessments of refuse collection and disposal operations, and social and cultural aspects of refuse operations.

10. Gunnerson, Charles, and John M. Kalbermatten, editors. Appropriate Technology in Water Supply and Waste Disposal. American Society of Civil Engineers Environmental Impact Analysis, Research Council, New York, New York, 1979.

The Inerternational Drinking Water Supply and Sanitation Decade will present major challenges to civil and sanitary engineers in both developing and industrial countries. Ready access to a minimum of twenty to fifty liters per capita per day of safe water, environmentally and socially acceptable means for waste disposal, and equitable cost recovery require assessment of conventional engineering practices during a period of increasing needs and decreasing fiscal resources. To this end, the Environmental Impact Analysis Research Council convened an ASCE Convention Session on Project Monitoring and Reappraisal. Generic principles of service levels, willingness to pay, and economic, technological and institutional development are presented, together with case studies in water supply and sanitation from both developing and industrial countries. These are followed by guidelines for engineering design, project monitoring, and project reappraisal. The guidelines lead to policies and practices in which (1) traditional and state-of-the-art skills are used, (2) case studies precede theory, (3) individual and community hygiene are stressed, (4) existing facilities are upgraded,

and (5) integrated systems for resource conservation and recovery are implemented.

11. Kalbermatten, John M., DeAnne S. Julius, and Charles Gunnerson, Appropriate Technology for Water Supply and Sanitation, Volumes 1-5 and 11.

This paper reports technical, economic, health and social findings of Research Project RPO 671-46, "Appropriate Technology for Water Supply and Waste Disposal in Developing Countries". The report discusses the program planning necessary to implement technologies available to provide socially and environmentally acceptable low cost water supply and waste disposal. Other volumes provide information and instructions on how to design and implement appropriate technology projects based on the findings reported in RES 24. They provide guidelines and design tools to the engineers and sanitarians responsible for planning and implementing sanitation projects. In addition, social and cultural factors influencing people's responses to water supply and excreta disposal technologies are investigated in eight case studies of communities in the rural and urban fringe areas of Latin America. Part 1 describes the methodology and questionnaire used to investigate how sanitation and water supply problems are perceived and to what extent people would be willing to participate in projects to improve their existing situation. Part 2 summarizes each case study, including the technologies introduced and community response to them. Part 3 represents the cross-community findings on perceptions, preferences, related practices, and the use of social science techniques to understand them. In part 4, the report focuses on the implications of the findings and suggests an approach which can be used by planners to integrate social and cultural factors into project design to ensure the introduction of water supply and excreta disposal technologies which will be accepted, properly used, and maintained.

12. Pickford, "Solid Waste in Hot Climates," in Water, Wastes and Health in Hot Climates, John Wiley Press, New York, 1976.

This chapter presents a discussion of the type of material from which refuse storage containers are made. It discusses the advantages and disadvantages of metal versus concrete bins and illustrates a successful type of communal container in Lagos, Nigeria.

13. Refuse Management in Developing Nations, U.S. Environmental Protection Agency, Office of Solid Waste, Washington, D.C., 1981.

In response to numerous requests from developing countries for information and assistance on management of refuse collection and disposal, the U.S. E.P.A. prepared a report that could be used by developing countries to help them

understand and implement an improved refuse management system. Refuse management is difficult in any nation since it requires a combination of land, labor, capital and management on a continuing basis. Often national and local governments are not fully aware of the many options in equipment and facility selection that can reduce long-range costs and labor/management problems and assure the success of the refuse system. Thus, this report is directed at decision makers in developing nations, to help them understand the problems and ramifications of their decisions on the success or failure of the refuse collection and disposal system.

14. Seldman, Neil, and Francisco Ospira, Solid Waste Collection and Disposal Project for the Metropolitan Area of Medellin, Colombia, The World Bank, Washington, D.C., May 1979.

This report is a discussion of the solid waste collection and disposal practices in Medellin, Colombia. It presents municipal refuse compositional data and the Medellin refuse generation rate. It focuses heavily on the traditional social, cultural and economic conditions which affect solid waste management systems, namely scavenging, and their grouping together into cooperatives to give them greater leverage in the marketplace.

15. Solid Waste Facts: A Statistical Handbook, U.S. Environmental Protection Agency, Washington, D.C., August 1978.

This is a book of solid waste statistics and facts of waste management in the U.S.

16. Subramanian, S.K., "Biogas Systems in Asia: A Survey" in Biogas Technology in the Third World, International Development Research Centre, Ottawa, Canada, 1978.

Biogas plants have found their greatest popularity in Asia where the number of installed plants have increased remarkably over the past two decades. This report was written as a background paper for a meeting on the social and economic evaluation of the biogas plant held in Sri Lanka and sponsored by the International Development Research Centre. It covers the historical development of biogas plants in India and present practices involving their use in India, South Korea, the Philippines, Thailand, Indonesia, and Japan. The report also discusses dominant social and economic issues related to the biogas plant in each country; problems of data collection and gaps in information; and finally the various technical approaches being used within the region.

17. Stevens, Barbara J., Handbook of Municipal Waste Management Systems, Planning and Practice, Van Nostrand Reinhold Environment Engineering Series, 1980.

This book reviews and discusses various solid waste management practices conducted throughout the U.S. Topics discussed include: crew size, truck configurations and capacities, productivity of crew and system, labor and union organizations, administration and organization of responsible departments, support and maintenance functions. The book concludes with a discussion of policy pitfalls that are often repeated by cities, and a list of policy guidelines based on the experience of the research.

18. Waste Streams and Integrated Resource Recovery Systems in Developing Countries (Draft), META Systems Inc., for U.S. A.I.D., August 24, 1981.

This report surveys existing technologies that can be used to form an integrated waste disposal and recovery system and reviews the technical, economic and social implementation of these systems. It also presents the results of waste recovery research in Israel and other countries, new developments and refinements of various component resource recovery processes, their experiences, and proposed improvements in current systems. The principle focus is on biogas and aquaculture.

19. White, G.F., D.J. Bradley and A.U. White, Drawers of Water: Domestic Water Use in East Africa, Univ. of Chicago Press, 1972.

Water supply improvements in the developing world have not kept up with population growth, especially in urban areas. To achieve maximum benefit from the expenditures made to remedy this gap, water projects must be based on greater knowledge of how water is used in community development and health. The conclusion drawn from this case study in East Africa is that, with both supply and disposal of water, once a minimum service is provided, the unit gain to health from units of improvement probably decreases sharply. Preliminary evidence, as indicated in this book, suggests that slow development of ideal "Western type" water systems should be set aside in favor of more rapid delivery of smaller quantitites of potable water to every household.

20. Yunus, Col. Muhammed, Solid Waste Management for the City of Lahore, Lahore Municipal Corporation, November 1980.

This paper is a wide discussion of solid waste management issues as observed in Lahore, Pakistan. It discusses street sweeping practices, refuse composition, generation refuse density, moisture content of the refuse and material recovery practices and potential.

BUILDING DESIGN AND MATERIALS

I. Technical Design Documents

1.1. Bowen, A., et al., eds., Proceedings of the International Passive and Hybrid Cooling Conference, November 6-16, 1981, Miami, Fl., American Section of the International Solar Energy Society, Inc., University of Delaware, Newark, DE.

The technical papers received for this conference represent a broad range of inquiry and experience with passive and hybrid cooling systems. Among these are numerous accounts of historical practices that remind us of the too-often forgotten or too-easily dismissed wisdom of our ancestors. At the opposite end of the spectrum are papers which report on the development of sophisticated new research tools and techniques, and results of these in assessing the performance of specific building components or assemblies. Cooling techniques for hot-dry and warm-humid regions are equally well represented under the topical areas of radiative, evaporative, and earth cooling, and ventilation and dehumidification. Controls on heat gain are also discussed in papers describing landscaping, shading, and daylight practices. There is a disappointing lack of papers offering "rules of thumb" and other schematic design tools which have proven to be so popular for preliminary sizing of solar heating systems. Perhaps this indicates a lesser developed state-of-the-art of analysis and prediction than exists in our sister science of heating; perhaps, too, it belies a greater complexity in the cooling problem itself, with its many available and interrelated pathways for dissipation of heat. The submissions received also seem to reveal that little work is underway in the field of bioclimatic analysis and assessing the regional suitability of efficacy of various cooling systems or practices. While reports are contained here on the performance of specific components or techniques at single test locations, few of these results can be extrapolated to other areas. Plainly, much work remains to be done with each of the cooling strategies in order to provide real guidance to the workaday practitioner. Nevertheless, the papers collected here compose a valuable resource to present and future workers, and we all owe our appreciation to those who contributed their time and effort in describing their work.

1.2. Evans, M., Housing, Climate and Comfort, the Architectural Press, London, 1980.

This book is probably the most comprehensive guidance resource available on energy efficient building design, methods and materials. The discussion of climatic analysis cooling technologies is thorough and specific to hot-humid/hot-arid climates peculiar to most developing nations A well illustrated manual, including a useful glossary, tables and other data given in metric measurements.

1.3. Konya, A., Design Primer For Hot Climates, Architectural Press, London, 1980.

This highly practical book has been written to encourage design solutions which are in harmony with local climates and conditions; a matter which, in view of the escalating costs of mechanical servicing, is increasingly recognized as one of economic as well as aesthetic importance. The initial chapters explain the fundamentals of climate and comfort. Subsequent sections set out environmental design techniques (both relating to the building itself, and to the use of vegetation); methods of dealing with hazards such as earthquakes, lightning, and termites; and finally give guidance on the use of locally available materials and technology. The emphasis throughout is on illustrated and tabulated practical advice, with many drawn examples of building form and construction, lists of suitable plant species, and the like. The book will be useful not only for professional designers and students, but also, it is hoped, for those who live in the dry areas of the world, encouraging them to question current accepted approaches to building design.

1.4. Olgyay, V.V., Design with Climate, Princeton University Press, 1963.

Well designed buildings can provide comfortable conditions without the use of expensive, energy-consuming mechanical equipment. This is only possible, however, if climate is taken into account from the outset; if it is taken into account when deciding on the overall concept, on the layout and orientation, and on the shape and character of structures among other things. Victor Olgyay, in this source, was the first to propose a systematic procedure for adapting the design of a building to human requirements and climatic conditions. His method is based on a Bioclimatic Chart on which comfort zones - one for Summer and one for Winter - can be determined for the climatic region to which it is to be applied. Once this has been done any climatic condition, determined by its dry-bulb

temperature and humidity, can then be plotted on the chart: comfort requirements can be evaluated; deviations from the comfort zone, and whether these can be eliminated by natural means, can be ascertained. This classic reference source is rather technical and useful more to the professional than a lay reader. However, this source has been the basis for all other literature on climate-conscious building design.

1.5. Stulz, R., Elements of Solar Architecture for Tropical Regions, SKAT - Swiss Center for Appropriate Technology, St. Gall University, 1980.

This publication aims at helping the layman to learn about some simple, inexpensive principles that may be applied in construction of new buildings and the improvement of existing houses. It may perhaps also serve the professional architect to recall those principles before starting off on a building activity. The brief booklet is by no means complete or exhaustive and concentrates on requirements for hot climates only. Neither solar heating aspects nor sophisticated technology for cooling or air conditioning are included but only simple things that can relatively easily be mastered.

1.6. Watson, D. and Labs, K., Climatic Design for Home Building, prepared for the NAHB Research Foundation and the U.S. Department of HUD, 1980.

This book is about designing houses to fit their particular climate. Climatic design is a simple matter to understand because it is based upon familiar experience and common sense about using energy sources available at every building site from the sun, wind, vegetation, and ambient temperature. Climatic design techniques take advantage of natural energy flows that result from heat gained or lost through the building's skin. Climatic design is the art of seeing to it that such heat gain or loss benefit the building occupants by creating physical and psychological comfort and by reducing the need for mechanical heating and cooling. There are illustrations on every page plus an excellent bibliography.

II. Building Materials and Techniques Documents

2.1. Elliott, S. and Wallas, E., The Timber Framing Book, META, Marblemount, Washington, 1977.

Timber-framing is a method of housing construction using interlocking notches and grooves combined with

wooden pegs to connect the major wooden beams. The method is labor intensive and requires tools not common to modern Western carpentry but still common and inexpensive in many Third World countries: the adze, auger, draw knife, chisel, and axe. Timber-frame houses built in Europe as early as the fourteenth century stand proud and sturdy to this day. Compared to conventional construction, timber-frame structures can be 20 to 30 percent less expensive to build. Less energy is expended in both the milling and the construction of the frame...if you have some basic carpentry skills you and some helpers can frame a house using the information in this book. If you do not, and have a carpenter in mind who has not previously used timber-framing, he can use this book to teach himself how. Where wood is plentiful the timber-framing methods of housing construction can be used to build houses of great durability (but you will have to look elsewhere for preservation information). Where wood is scarce, soil-cement, adobe and other wood-conserving construction materials would be more appropriate. There are illustrations and pictures on almost every page, and a thorough glossary.

2.2 McClure, F., Bamboo as a Building Material, U.S. Department of Housing and Urban Development, 1972.

The how-to material with the aid of photos in this booklet show techniques of fastening bamboo without the use of nails, and various uses of bamboo in building construction around the world. In addition, there is a rather general 5-page discussion of the use of bamboo in housing. Another section is given to bamboo reinforcement of concrete; this is a reprint of a technical summary of conclusions from tests on concrete beams. Problems include bond between bamboo and concrete, and swelling that occurs when seasoned bamboo absorbs moisture from wet concrete. While many houses have been built with only a machete, more refined or elaborate structures might require some of the handtools briefly described (no illustrations). The booklet also includes a lengthy list of bamboo types used around the world, and a 60-entry list of selected references up to 1953.

2.3. National Academy of Sciences, Roofing in Developing Countries: Research for New Technologies, Washington, D.C., 1974.

The most serious obstacle to low-cost housing in the developing countries, regardless of setting or sophistication, is the lack of low-cost roofing material that will provide satisfactory performance for a reasonable time under many adverse conditions...In many

developing countries roofing alone represents more than 50% of the total construction cost of a low-cost house. An attempt is made here to identify materials that would last longer than thatch/fired clay and yet be cheaper than imported corrugated iron. The use of plastics, foam composites, sulfur, carbonized plant materials, asphalt, hydraulic cement binders, argriculture and wood wastes, and ferrocement is discussed. The qualities and research needs for each of these are pointed out. The work of the Central Building Research Institute of India is briefly described. This is an overview only of promising new technologies.

2.4. United Nations Department of Economic and Social Affairs, The Use of Bamboo and Reeds in Building Construction, 1972.

Bamboos and reeds are the oldest and chief building materials in rural areas and villages throughout the world's tropical and subtropical regions. More people live in bamboo and reed buildings than in houses of any other material. Bamboo and reed construction is popular for good reasons: the material is plentiful and cheap, the villager can build his own house with simple tools, and there is a living tradition of skills and methods required for construction. This tradition has been augmented in recent years by experiments carried out principally in India, Indonesia, the Philippines and Colombia. The bamboo and reed house is easily built, easily repaired, well-ventilated, sturdy and earthquake resistant. Deterioration by insects, rot, fungi and fire is the chief drawback of bamboo and reeds as building materials. This study was produced to inform government planners, extension officers, contractors and villagers of new or less well-known techniques of construction, and to stimulate additional research to improve the material properties and techniques of building construction with bamboo and reeds. Included are descriptions with photos of common uses of bamboos and reeds, drawings of a wide variety of joints used in building with bamboo, a summary of research (now 25 years old) on concrete with bamboo and reed reinforcing, strength data on selected bamboo species used in construction, tools and species lists, and preservatives for different bamboo end uses.

2.5. Vietmeyer N.D., et al., eds., Ferrocement: A Versatile Construction Material: Its Increasing Use in Asia, Asian Institute of Technology, Bangkok, 1976.

These are the proceedings of a workshop held in Bangkok in November 1974. It offers a general survey

of ferrocement use and research in Asia, including activities in Korea, Fiji, Thailand, India, Sri Lanka, Malaysia, Singapore, Papua New Guinea and Bangladesh. The economics, labor and materials requirements, versatility and durability are explored. Specific construction details are usually not included, although some of the things described - for example, the water jars - could be built using only the instructions in this book. In India ferrocement is being introduced for silos in sizes to hold about 1 to 30 tons of grain. Methods developed for ferrocement boat building are being applied to these storage structures to obtain a structure of high quality. Ferrocement products discussed include boats, housing, food and water storage silos and tanks, roofing, biogas plants, road surfaces and tube well casings. Over 60 photos and drawings.

2.6. Wolfskill, L., Handbook for Building Homes of Earth, U.S. Department of Housing and Urban Development, Washington, D.C., n.d.

This is a very complete, all purpose manual covering all types of earthen housing construction, including adobe, rammed earth, and pressed blocks. The manual covers many areas: different types of soils, testing soil, soil stabilizers, building site preparation, foundations, roofs, and preparing soil. In addition, each of the three major types of earth construction (adobe, rammed earth and pressed blocks) are covered separately and extensively. There are detailed chapters on how to make different kinds of blocks, and how to build structures with them. The **Handbook** is a very comprehensive book, useful in many different climates and regions - for example, there is information on soil cements applicable to humid, tropical climates where protecting earth structures from the rain is important. This book is extensive in the amount of useful information it has about soils. Recommended as a very complete book on all forms of earthen housing. Photographs and illustrative drawings are included.

III. Planning and General Documents

3.1 The AIA Research Corporation, The Community Energy Design Primer, The American Institute of Architects, 1980.

When considering energy saving strategies at the community scale, a framework should be developed that structures activities and accommodates growth and change in an orderly and efficient manner. The planning mechanism has accommodated similar emerging con-

cerns quite successfully in recent years. Through community planning, a procedures is available to locate and organize seemingly unrelated activities which nonetheless interact to determine community energy consumption patterns. Energy considerations, once integrated into the ongoing planning process, lead to more responsive land use patterns, building densities and transportation systems. With this broadened framework in place, the groundwork is laid for more specific, energy efficient projects within the community. This book addresses various planning tools a community can undertake to promote integrated energy strategies with an emphasis on building.

3.2. Fathy, Hassan, Architecture for the Poor, University of Chicago Press, 1973.

Hassan Fathy is an Egyptian architect. He strongly feels housing should be based on traditional forms of architecture, not those forms imported from the West. The people themselves should be intimately involved with the design, building and ownership of their own housing. When the government or private contractors step in and build for the people, the result is often housing and planning which is vastly out of touch with local social, cultural, economic and environmental conditions. This book describes in detail Fathy's plan (during the 1940's) for building the village of New Gourna, Egypt, from mud bricks, employing almost exclusively such traditional Egyptian architectural designs as enclosed courtyards and domes and vaulted roofing. Fathy worked closely with the people to tailor his designs to their needs; he taught them how to work with the mud bricks, supervised the erection of the buildings, and encouraged the revival of such ancient crafts as claustra (lattice designs in the mudwork) to decorate the buildings...In addition, Fathy worked out an economic and organizational base, so that the production in the village derived from local crafts and organizational patterns. Although bureaucratic and other problems prevented the completion of New Gourna, Fathy argues convincingly from the necessity of simple, traditional housing in developing areas that can be built by the people themselves. They would use local materials and adapted traditional building methods. Today Fathy's ideas are becoming more accepted as development becomes more of a priority throughout the world. There are more than 100 photographs and some design sketches included.

3.3. Flavin, C., Energy and Architecture: The Solar and Conservation Potential, Worldwatch Institute, Washington, D.C., 1980.

The energy problem is, in some measure, an architectural problem. Modern buildings have until recently been constructed with little heed paid to their energy efficiency or lifetime fuel costs. The buildings sector, like other parts of the world economy, has been accustomed to low, subsidized fuel prices. The prevailing assumption was that efficiency of energy use was unimportant because technological developments would continue to keep fuel prices low. The price of this shortsightedness is borne by millions of consumers in their monthly fuel bills. This book discusses the current situation with respect to the energy and architecture dilemna. Overall it is a good introduction to the problem areas, trends for the future and some of the programs communities have enacted to curtail energy inefficiency through climate sensitive design.

3.4. Stokes, B., Global Housing Prospects: The Resource Constraints, Worldwatch Institute, 1981.

This book is an overview of the problems associated with the demand for adequate and economic shelter. This discussion of the constraints placed on housing provisions for a rapidly growing world population is quite thorough. Many examples are given of how various cultures are attempting to improve housing and keep pace with diminishing resources.

3.5. U.S. Department of Housing and Urban Development and U.S. Department of Energy, Regional Guidelines for Building Passive Energy Conserving Homes, 1980.

A building separates inside spaces from the outside environment with the primary purpose of creating comfortable conditions for the occupant. Mechanical systems are designed to provide heating and cooling whenever outside conditions make the inside spaces uncomfortable. One of the most effective ways to save energy in residential buildings is to build responsively to the outside climate and thereby reduce dependence on mechanical systems. Energy conservation involves building to isolate the interior of a home from an 'alien' climate, and passive design involves opening the same interior to a 'friendly' climate for natural conditioning. This report gives specific guidelines in narrative and illustrative form useful to the lay reader. The manual provides good introductory techniques for all climate conditions.

3.6. Watson, D., "Energy Planning for Developing World Cities: Opportunities in Integrated Approaches to Urban Infrastructure, Light-Industry, Commerce, and Building", Housing Science, Vol. 4, No. 5, 1980.

Energy planning can improve the quality of urban life and the environment in the developing world. Although this may appear to be obvious, long-term energy and resource costs have not been an important enough concern in planning projects in the developing world. When it is considered, the usual emphasis is on energy production. The ultimate value of energy production capability, however, is directly related to end-use consumption, which influences the peak capacity, the unused or lost energy, and the amount of pollution that inevitably results when conventional fuel sources are used. Energy is used most efficiently when it is delivered at as near the same "grade," or temperature requirement, as required at the end-use. Because of this, conservation efforts are an essential part of energy planning to improve the economic value and to reduce the negative environmental impact of any development that produces or uses energy. The city is an investment in the future. Particularly in the new cities of the developing world, the economic and environmental qualities that will be available to future generations are established by current investments in urban infrastructure, urban enterprises, and services. If energy and environmental resources are not considered when plans are set in motion, future choices are greatly limited. On the other hand, opportunities for new approaches to urban settlements exist, based upon our most recent technological innovations in renewable energy and ecological systems planning. In new cities, or ones that are still expanding, major planning decisions can be made to balance urban growth and development with social and conservation needs, to improve the efficiency of urban infrastructure and transportation, to initiate new businesses and industries, and to create beautiful buildings and urban spaces. Such opportunities must be acted on. In the industrial world, decisions that determine urban structure were made generations ago, often without benefit of planning and based upon technologies that from an energy standpoint are outmoded and costly. For this reason, the unprecedented cases for truly innovative energy planning exist now in the cities of the developing world. This report focuses, firstly, upon the opportunities for energy planning created by integrating solutions to urban energy systems, commercial and small-scale industrial development, and building construction and renovation, and secondly, upon the role that might be served in responding to these opportunities by international aid and technical assistance.

IV. Case Studies

4.1. The Architects Collaborative, Inc., "Terraced Pods Invite Daylight and Breezes." Architectural Record, Mid-August 1981.

This article covers a major architectural project being constructed in the Philippines using the passive energy principles of ventilation and daylighting. Each aspect of the building design that promotes energy efficiency is discussed along with conceptual explanations of the various techniques used for the model.

4.2. Diachok, D. and Shanks, D., International Passive Cooling Survey, Solar Energy Research Institute, Golden, Colorado, 1980.

This volume is a compilation of scholarly papers covering specific aspects of passive cooling. Examples of passive technologies worldwide are included plus many theoretical, but promising applications. This publication is oriented to the professional user.

4.3. Watson, D. and Bertaud, A., "Indigenous Architecture as the Basis of House Design in Developing Countries: A Case Study Evaluation of Traditional Housing in Bhutan," HABITAT, Vol. 1, No. 3/4, 1976.

This paper discusses criteria for new housing design based upon traditional building solutions that are indigenous to a specific locale, climate, and culture. It is argued that the study of indigenous architecture can contribute to new building design criteria, which too often are based on styles and construction methods that are not properly matched to the ecological and cultural needs of a nation under development. Illustrative material is drawn from a case study of traditional housing in Bhutan.

4.4. Watson, D., Passive Energy Principles For Housing in Mexico, A Report for the Solar Energy Research Institute (SERI) International Programs, U.S. Department of Energy and the Republic of Mexico (SAHOP), 1980.

This report outlines an approach to housing design in Mexico based upon climatic criteria. Climatic design techniques take advantage of natural energy flows that result from heat that is gained or lost through the building envelope. The goal of climatic design is to achieve comfort conditions with the best use of available resources. Generally, this involves the design of the building based upon specific sun, wind, water, and air and ground temperature available at the

building location. Each of these climatic impacts can have either a detrimental or a beneficial effect on comfort conditions. The Mexican climate types range from temperate to hot-dry and warm-humid zones. In warm climatic zones, as are found in Mexico, the principal requirement is to create comfort in overheated conditions. For housing, this involves passive cooling techniques, including sun control and temperature moderation through time-lag. In climatic zones where the daily temperature swing ranges from warm days to cool or comfortable nights, time-lag effects can be combined with night ventilation. If there is an annual temperature swing that includes moderate or cool winters, ground termperature heat exchange techniques might be exploited, such as through underground or earth-sheltered design. In warm-humid zones, the principal natural cooling technique is ventilation. Passive solar heating techniques that are suited for predominantly warm or temperate climates principally rely upon time-lag effects and the size and placement of building walls and windows. Lack of the designer's understanding of the dynamics of sun angles can result in buildings being overheated due to undesired solar gain, imposing a cooling requirement where none should exist. For building types other than housing, such as office buildings, the requirement for comfort is combined with the need for lighting and therefore involves the design of sun control devices that achieve sun shading and natural illumination. In this report, the specific climatic profiles of representative Mexican locations are presented with reference to the psychrometric chart that indicates the predominant passive design techniques that are applicable. The climatic design principles that might be considered are reviewed. Combined passive heating and cooling techniques appropriate to temperate zones are described. Climatic design research needs are also discussed with reference to large-scale building programs and experimental projects.