Chapter **54**

Information to Improve Decision Making for Health

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The new source of power is not money in the hands of a few, but information in the hands of many.
—John Naisbitt and Patricia Aburdene, Megatrends 2000

This chapter focuses on the collection and management of public health information, in contrast to clinical information, which concerns individual patient care encounters. Even when aggregated, clinical data are necessary, but not sufficient, to inform efforts to improve the health of populations. While substantial attention has been focused on these facility-based clinical consultations and the health management information system (HMIS) used to track the relevant data, we focus here on the broader health information system (HIS) needed to inform decisions at individual, facility, district, and national levels. Considered here are the routine data collection systems upon which program management, planning, monitoring, and evaluation depend. Information needs for specific tasks, such as for research or for program evaluation, are discussed in the chapters on research (chapters 4 and 7). Other chapters in this volume refer to information needs to enable disease control or to evaluate programs and improve the delivery of interventions. Those interested in these issues should also pay special attention to chapter 53 and chapters 70–73. This chapter bridges the global and the local issues; it makes the case for strengthening the evidence base for action through comprehensive health information systems that include census, vital events, monitoring, public health surveillance, resource tracking, facility-based service statistics, and household surveys.

INTRODUCTION

From infancy on, we receive information that gives form to our thinking and problem solving. The method by which a phenomenon is measured shapes societal perceptions of it and the collective efforts to affect it. Likewise, the choices we make in the collection and use of information for health will determine our effectiveness in detecting problems, defining priorities, identifying innovative solutions, and allocating resources for improved health outcomes. Despite those fundamental realities, there has been little awareness to date of the ramifications that greater information use can have for advancing health, and even less attention has been given to systems needed to provide timely, accurate, and relevant information.

An example of the formative power of information for policy change lies in the history of the United Nations' Standard System of National Accounts, created by Richard Stone more than 50 years ago. The annual reporting of these accounts by most countries shapes our impressions of the relative position of nations, defines our views of the differential opportunities offered to their citizens, and drives the content of national and global political discourse (Jolly 2002). Another example is the measurement of disability-adjusted life years (DALYs), which has shaped priorities for investment in global health over the past decade.
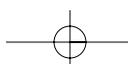
However, data or information alone will not transform outcomes. *Data,* which are simple measures of characteristics of people and things, have little inherent meaning or value. Analysis of the data enables the identification of patterns, thereby creating *information.* Finally, the use of information to generate recommendations, rules for action, and behavior change signifies the creation of *knowledge* that is used to make decisions and change human behavior.

Good decisions on effective policies, services, and behaviors require timely, accurate, and relevant information. Health information is required for strategic planning and the setting of priorities; clinical diagnosis and management of illness or injury; quality assurance and quality improvement for health services; detection and control of emerging and endemic disease; human resource management; procurement and management of health commodities (including drugs, vaccines, and diagnostics); regulation of toxic exposures; program evaluation; research; and other types of policies and programs (Walsh and Simonet 1995). Citizens require such information to choose healthy behaviors, to demand effective policies and services, and to hold their governments accountable for the allocation and use of resources for health. Internationally, information is required to meet transnational needs, such as for the detection and control of consequences of epidemics and infectious diseases, results-based management of development assistance programs, and advocacy for increased financing for health.

Several recent trends further enhance the pressures to deliver better health information. Global epidemics, such as of severe acute respiratory syndrome (SARS) and "bird flu," have amply demonstrated the need and potential benefits of sensitive and transparent systems for tracking health events. Donors, including the Global Fund and the Global Alliance for Vaccines and Immunization (GAVI), increasingly demand performance measures and detailed evidence to justify new requests for support. "Basket" funding and sectorwide approaches place further responsibilities on countries to define their own priorities. Decentralization and devolution of budgetary controls have shifted much of this growing burden to the periphery, requiring districts to provide local evidence as a basis for decisions. Tracking progress toward the Millennium Development Goals for health requires empowering countries to measure key indicators and produce evidence-based strategic plans to achieve and document that progress. Furthermore, nearly every chapter in this volume cites the need for better information, including through research dependent on a health information system, to accelerate improvements in health.[1]

Yet there is a striking disconnect between the need for information and the ability to respond to that need. To collect, collate, analyze, and communicate the necessary information in a timely and understandable fashion requires organized processes and procedures and a comprehensive HIS. However,

donor-driven and disease-specific initiatives have actually undermined efforts to develop a comprehensive HIS by creating separate, parallel, and often duplicative systems to meet the need for each funding source.

Health information and the systems for its supply are a public good, meeting the defining criteria of being *nonexcludable* (in that, once the information is in the public domain, it is difficult to withhold from users) and *nonrival* (in that consumption of the information does not lessen its availability for use by others). As a public good, the supply of health information is the primary responsibility of governments: national governments for information within these jurisdictions, and international agencies and national governments together for international comparative information and global summary data.

Harmonizing the data collection, standards, best practices, and other elements of a national and global HIS has several advantages. Standardization enables economies of scale for training, hardware and software, and processes. Routine health information is a summative good in that the collation of each contribution produces a cumulative increase in the value of the public good, strengthening the credibility and importance of that information. Furthermore, standardization of systems improves the reliability and comparability of information, both within nations and across national and regional boundaries (Cibulskis and Hiawalyer 2002).

SYSTEMS AND SUPPLY OF HEALTH INFORMATION

To create an effective HIS, governments must finance the system, create the necessary policy environment (for example, through legislation and regulation), and develop systems and services for the collection, collation, dissemination, and use of health information. A substantial portion of the national health information is fully within the control of government health officials. However, information from the private health sector and other parts of the government is also required. Table 54.1 lists some of the data required and their sources. A principal challenge is the integration of these intra- and extrasectoral functions into a single, comprehensive HIS.

Direct Expenditures for Health Information

As for most public goods, the production of health information is mostly financed by government appropriation. Budget support for the HIS comes through both the ministry of health and a national statistics office (NSO) in most countries. The NSO is usually responsible for collecting information through the national census and most household surveys. For the least developed countries especially, bilateral and multilateral donors are essential sources of finance, particularly for HIS planning, infrastructure development, and training. In Africa, it has been estimated that grants or loans from donors account for between 20 and 70 percent of the financing for statistical

Table 54.1 Health Information from Sources Outside the Health Sector

Health information	Responsible agency
Census and national surveys: Income and poverty distribution Household expenditure for health Coverage with health interventions	National statistical office
National expenditures for health, economic development indicators, and industrial production and distribution data	Ministry of finance
Employment data: Human resources for health Occupational health information	Ministry of labor
Import data: Pharmaceuticals and vaccines Capital equipment and health commodities	Ministry of trade
Food production and security information and nutritional status data	Ministry of agriculture
Military health service statistics	Ministry of defense
Patterns of transportation injury (including motor vehicle accidents)	Ministry of transportation
Literacy rates and school health program information	Ministry of education

Source: Authors.

systems overall. Revenue generated by selling statistical products and services accounts for 10 to 20 percent of the financing for national statistical systems (Economic Commission for Africa 2003). User fees or taxes for use of information products and services can partially offset the costs of developing and maintaining the information system. In many countries, taxes and tariffs on computer equipment and government regulation of communications and Internet use remain barriers to public access to health information. Cost must not be a barrier to use of health information for the public good.

Information Policy

Sound information systems require a legislative and regulatory environment that encourages and supports effective HIS development. At the global level, many efforts have been made to establish international standards and policy frameworks for statistical data (United Nations Statistical Commission 1994). These policy frameworks are used to establish mandates for collection of basic health data (such as a decennial census or surveillance for reportable infectious diseases), to ensure the independence of official statistical agencies, to reinforce professional ethics, and to create norms for data quality and dissemination.

Another key policy intervention, less tangible though equally critical, is the creation of a culture of quality and transparency

in the management of health information. There should be protection from political interference and full empowerment of the health statistics office to make public statements in response to criticisms of reports and the underlying methods. Ethical practices for protecting privacy and confidentiality must be well understood, and procedures should be in place to deal with breaches in these standards. Accuracy and reliability should be stated as expectations and ensured through periodic review of data collection methods and through benchmarking with internationally credible definitions of indicators. A client orientation should be instilled and users of data regularly consulted in defining outputs and formats for the presentation of data.

Systems for Collection, Management, and Analysis

Most developing countries have no comprehensive strategy for information management, reflecting the fractal nature of donor and national investments in these systems. Interventions to improve the HIS in the least developed countries, often donor driven, have often focused only on a specific subsystem, primarily for health service statistics, and have neglected other components of the HIS.

An effective HIS requires an overarching architecture that defines the data elements, processes, and procedures for collection, collation, presentation, and use of information for decision making throughout the health sector (see box 54.1). This information architecture promotes comparison and integration of data elements from a variety of subsystems. As O'Carroll (2003) points out, such a comprehensive design enables phased system development, reduces redundancy, increases efficiency, and improves interoperability. Interoperability is critical to ensuring, for example, that census data, vital statistics, and health facility data can be integrated to generate rates, ratios, cost-effectiveness estimates, and other information required to compare options for health investment.

The Pan American Health Organization (PAHO) has led the Regional Core Health Data Initiative "to facilitate speedy access to basic information on the health situation in the countries of the Region." This initiative has involved an international consultation and agreement on the priority data, collection methods, and indicators. The initiative has shown that it is possible to create a regional database of essential, consistent, valid, standardized, timely, and regular information. PAHO has used the information to set its priorities, whereas countries have applied the results to design health programs and to allocate resources to upgrade their information systems. In the future, the plan is to expand the systems to subnational districts (PAHO 2004).

Other WHO regions, including the Asia Pacific, are instituting similar initiatives with Web-based publication of core health indicators.

Data Collection. No single mechanism for data collection is adequate to meet the needs for public health decision making.

Box 54.1

The Health Metrics Network: Harmonizing Investment in HIS Development

Developing countries, multilateral agencies, bilateral donors, and technical resource agencies have recently come together to form a global Health Metrics Network (HMN) that is designed to provide guidance for the development of the HIS, both in meeting national information needs and in producing the required indicators for tracking progress toward global goals**.** The HMN will provide the first consensus technical framework for HIS

architecture and a plan for development of national health information systems. This HMN Framework includes a blueprint for iterative improvements in the HIS; descriptions of core data collection subsystems (census, surveys, vital events monitoring, service statistics, and resource tracking); and procedures for management and dissemination of information.

Source: Authors.

These needs can be met using a combination of the six key health information subsystems: census, household surveys, public health surveillance, vital events monitoring, health service statistics, and resource tracking. Surveys are conducted on a sample in order to limit costs, whereas the other subsystems are more often designed to cover the entire population. In most developing countries, public health surveillance—except for certain disease-specific efforts—is conducted through passive reporting from health facilities. Especially where utilization rates are low, this facility-based surveillance may be considered a sample or "sentinel" surveillance strategy. Vital events monitoring is, ideally, universal; however, many countries use a phased introduction of vital events monitoring that makes it functionally a sentinel or sample-based data collection effort during the transition to universal coverage.

A *national census* every 10 years is an irreplaceable component of a national information system because it provides denominator data for so many indicators and sampling frames for subsequent sample surveys. The major costs of a census come from activities to establish the census maps, enumerate populations, enter data, and analyze the results. The cartographic costs can often be shared with other government departments, because the resulting updated maps can be instrumental in carrying out other critical public functions.

Sample surveys of households are a mainstay of health information collection in the developing world. They provide data on service utilization; coverage of health interventions (for example, immunization); morbidity (self-reported illness or disability); pregnancy outcomes; mortality levels, differentials, and trends; and causes of death (through associated *verbal autopsy;* that is, expanded interviews in the case of death to determine cause on the basis of signs and symptoms before death).

Surveys are, almost without exception, funded externally in the least developed countries and are not seen within the country as being part of a health information "system." They are, in

fact, generally undertaken to compensate for the lack of information available through routine systems (AbonZahr and Boerma 2005). The investment in surveys has thereby enabled donors and developing countries to sustain their neglect of the development of comprehensive and sustainable national health information systems. The United Nations Population and Statistics Divisions and the European Statistical Office (EUROSTAT) also support household survey work. Differences in methodologies among these surveys are currently a barrier to the comparison of results. The World Bank's Managing for Development Results Roundtable, held in Marrakech, Morocco, in 2004, recommended harmonization of these surveys to eliminate duplication.

Nonetheless, surveys offer an important source of information that transcends most of the selection bias that is inherent in service statistics. Especially in the least developed countries, where vital events registration systems and census taking are embryonic or nonexistent, surveys represent the only source of unbiased information about demography, socioeconomic status, coverage, morbidity, mortality, health expenditures, and other characteristics of the population. Where substantial proportions of the population use private health services, household surveys are particularly important. Even industrial countries rely on periodic community-based sample surveys for immunization coverage, for health service utilization rates, and for information on household health expenditures (Perrin, Kalsbeek, and Scanlan 2004).

The World Health Organization (WHO) recommends using periodic surveys to monitor coverage, such as for immunization programs, especially in view of the shortcomings of service statistics for obtaining these measures (Murray and others 2003). Some household surveys collect biological and clinical specimens, such as blood, saliva, urine, and self-collected vaginal swabs, or they check swabs for anemia, HIV, disease antibodies, vitamin A, and other conditions. However, the performance characteristics of most diagnostic technologies (for example,

cost, ease of field use, sensitivity, and specificity) are designed for clinical use and do not lend themselves readily to use in population surveys, especially in remote areas of developing countries. Moreover, the collection of diagnostic information along with individual identifiers introduces complex ethical issues in the notification of people with treatable conditions, the financing of any required treatments, and the use of the specimens for other studies (Ties Boerma, Holt, and Black 2001).

Public health surveillance has been defined as the "ongoing systematic collection, analysis, and interpretation of data on specific health events affecting a population, closely integrated with the timely dissemination of these data to those responsible for prevention and control" (Thacker and others 1996). In developing countries, surveillance usually focuses primarily on a set of notifiable diseases, mainly infectious, which health care providers and laboratories are often required by law to report. Some nations also track risk factors for important diseases, injury events, adverse drug reactions, cancers, and pregnancy outcomes. Surveillance may be intensified over a period of years to enable targeting of special interventions for the control or elimination of diseases such as polio, tetanus, or measles. Active surveillance or screening of populations for target diseases may also be used in specific circumstances, such as during peak seasons for the disease or during natural disasters, when the potential for epidemics may be high.

Most passive surveillance data, however, are incomplete. Reliance on surveillance for reportable diseases diagnosed in health facilities omits diseases diagnosed among those who go to private providers or who are too poor to go to any health facilities. Even in health facilities, reportable diseases are often underrecognized or cannot be confirmed in laboratories that have inadequate resources. Sentinel surveillance methods and registries maintained in a few selected sites may be more representative of the entire population and more cost-effective in identifying and reporting the target diseases or health conditions; however, an outbreak may go undetected in a geographic area without a sentinel site. Special regional surveillance may also be used where populations are vulnerable to special health risks. The Vigisus project in Brazil, for example, has developed a system of epidemiologic and environmental surveillance for the prevention and control of disease among indigenous populations in the Amazon region (http://www.br.undp.org/propoor/BRA97028a.htm). Despite the methodological hazards, public health surveillance is essential for both national and global planning and preparedness, especially in view of the risks of regional expansion (for example, of meningitis and polio) or global spread of recent epidemics (for example, of SARS and bird flu).

Vital events monitoring is the continuous, compulsory, and (in most cases) universal civil registration of key vital events, such as births, deaths (sometimes including fetal deaths), marriages, divorces, and migrations. In many countries, vital events monitoring systems function poorly and may be found only as remnants of past colonial administrations. In 2003, 115 of 192 WHO member states reported mortality data with causes of death, capturing about one-third of global deaths, or 18.6 million deaths per year. In South Asia, only 60 percent of births are registered (22.5 million), and in Africa, only 30 percent (17 million). Alternatives to universal registration include the sample registration systems used in China and India and the demographic surveillance sites in Tanzania. The International Network of Field Sites with Continuous Demographic Evaluation of Populations and Their Health in Developing Countries (INDEPTH), an association of longitudinal vital and health statistics surveillance sites in 17 countries, can provide technical support and training for development and management of these demographic surveillance sites (http://www.indepth-network.org/). The UN Statistics Division has developed principles and recommendations for vital statistics systems to guide countries in their development (http://unstats.un.org/unsd/demographic/sources/civilreg/civilreg methods.htm.)

Vital events monitoring systems may also be enhanced to determine causes of death, whether those deaths occur within health facilities or in the community. When deaths occur outside the health care system, a *verbal autopsy,* or structured interview of the relatives of the deceased, can assist in determining the cause of death. Verbal autopsies can, however, be used reliably to diagnose only those few conditions that have characteristic clinical signs or patterns of signs that can be recognized by family members or by the health workers who review the interview data. WHO is now developing standardized tools for verbal autopsy that will enhance the sensitivity and specificity of these instruments and permit comparisons over time and across geographics.

Health service statistics are critical management tools for both preventive and curative services. The statistics are collected at each level: community outreach service points, primary care facilities, and district and regional referral hospitals. Information from clients and providers documents the quantity and quality of services and enables managers to detect and solve problems in order to improve health outcomes and efficiencies. This health information subsystem must be "flexible and capable of adapting to local needs, while at the same time allowing for standardization of health care quality assurance indicators, and subsequent ability to measure and compare the quality performance of health facilities nationwide" (Duran-Arenas and others 1998). A principal barrier to improving service quality in many health care facilities is the lack of reliable systems for managing and retrieving individual patient records.

Service statistics are especially powerful when they can be compared with population-based measures from censuses and surveys to estimate rates and ratios, such as disease incidence or

service coverage rates. Most service statistics subsystems track data only from public sector providers and facilities. Future improvements must implement systems and incentives to ensure reporting of service data from the private sector.

The *resource-tracking subsystem* must enable measurement and management of human resources; facilities; commodities (pharmaceuticals, vaccines, and other consumables); and finances. Human resource tracking provides a mechanism for licensing health service providers and accrediting health facilities. Licensure and accreditation can be paired with incentives to ensure service quality and private sector contributions to achieving public health goals.

The national health account (NHA) framework provides methods for measuring total national expenditures for health from household, public, private, and donor sources. NHA data document the sources of health financing, the amount spent for services, the distribution of funds across services and interventions, and the distribution of health benefits from those services and interventions. An NHA framework tracks the flow of funds, for example, from the ministry of health to health providers and government service programs or from households to pharmacies and private providers. These internationally comparable data enable benchmarking of performance among countries (Peters and others 2000).

Of the 68 countries that have implemented NHAs, only one-third have used the framework more than once. However, 19 of 21 countries studied can report at least one instance in which the NHA system has informed and shaped policies (De and others 2003). For example, South Africa's NHA analysis documented a higher per capita health expenditure in the richest districts, leading to intensified efforts to mitigate these inequities (Abt Associates 2003).

Information and Communications Technologies. The rapid evolution of information and communications technologies (ICT) over the past 30 years has immense implications for the potential speed, cost, and effectiveness of an HIS. But a "digital divide" persists, with poor countries failing to benefit fully from these ICT advances. Lack of access to reliable power sources, absence of Internet connectivity, inability to procure computer equipment and appropriate software, and inadequate technical support are some of the barriers. African users account for only 1 percent of the world's Internet traffic, 80 percent of which is in South Africa (http://www3.sn.apc.org/africa). Although less than 0.001 percent of the Internet use in Africa is among health professionals, this usage is growing rapidly.

Internet access in health facilities can make the HIS more effective and efficient by enabling instantaneous transmittal of data to central locations. Internet access in facilities can also speed data transmission and improve clinical outcomes by providing access to evidence-based decision support for clinical care (Godlee and others 2004; McLellan 2001). Even in remote

areas where no telephone or cable access exists, satellite technology can provide access to e-mail. Several countries, such as Bolivia and Peru, have successfully used satellite telephone technologies to enable continuous Web-based updating of health databases. Because the effectiveness of epidemic control often depends on timely detection and reporting of outbreaks, e-mail and telephone technologies have shown particular promise for use in disease surveillance. In Peru, for example, 100 percent reporting was achieved and sustained within six months of rollout of a pilot surveillance system using cellular telephones (Lescano and others 2003). The system is to be expanded to national coverage this year.

Although individual citizens will not soon have equal access to ICT, these technologies can immediately be better used to improve public health. Automation of data entry and analysis can ease data capture, validation, analysis, and transmittal of health information. District managers can generate reports with tables and charts and transmit them to central levels, which can then apply this knowledge to improve local management. Special prompts and "exception reports" can alert managers to unexpected findings that require double-checking or immediate interventions (for example, outbreaks of infectious disease, low immunization coverage, or other management problems).

Use of free software, such as the U.S. Centers for Disease Control and Prevention's Epi Info, can lower costs, but often these software packages require substantial adaptation to local needs, along with additional training and technical support. Acquisition of computer equipment should be viewed not as a one-time capital expenditure but as a long-term commitment to buy periodic upgrades, maintenance, and technical support. Experience shows that purchase of inexpensive software and computers, such as in the Eastern Cape Province of South Africa, may actually increase overall costs when they require early replacement with more adequate alternatives.

Geographic information system (GIS) technologies have also been successfully used in districts in several countries to enable mapping and visual representation of the geographic distribution of risk factors, disease, and services. A desktop GIS viewer and mapping software are available in several shareware versions, including the WHO's "Health Mapper," so that maps can be produced at little cost. Other potentially promising technologies include electronic scanners and personal digital assistants for data capture (http://www.healthnet.org) and global positioning systems to facilitate the mapping process.

The principal barriers to improved information systems, however, are human, not technological. Substantial investment in training and technical support must accompany the introduction of any new technology. If the HIS is not functionally solid, introducing ICT will likely only worsen existing problems.

Dissemination and Use of Health Information

Information is a means to the end of improving health, but the availability of reliable information does not guarantee its use or improved decision making. Because decisions are often driven as much by politics as by evidence, it is critical to design information systems to meet the needs of decision makers and to create a culture of evidence that provides incentives and accountability for evidence-based decision making. Extensive dissemination promotes widespread use and accountability. The many users of information include the following:

- health ministries at national, regional, and district levels
- researchers and evaluators
- legislative and policy analysts
- nongovernmental organizations and consumer organizations
- advocacy groups
- private sector health providers and insurers
- communities, including groups of patients
- journalists
- donors and international agencies concerned with health
- individuals and families.

The literature on health information systems is replete with complaints of the neglect of existing information, yet remarkably little is known regarding the effectiveness of interventions to improve the use of information. The NHA experience (De and others 2003) suggests that policy makers are most likely to use information when it contributes to and informs a preferred government direction, especially if that information is not available to stakeholders outside the health ministry. But systems and dissemination patterns for information can be engineered to ensure that clients, providers, and managers will seek and use information to inform decisions. Standard procedures can be developed to ensure analysis and use of data at the level at which it is collected. Training of health workers can be designed to include both basic and refresher training in the analysis and interpretation of data that are relevant to each job. Expectations of information use can be built into routine job requirements, including use of evidence for planning, data requirements for periodic reporting to supervisors, and use of information during performance reviews. Groups of managers can be convened across districts or regions for benchmarking, in which each manager presents and compares performance data and is rewarded for transparency and learning. These practices will result only from intense training in analysis and use. For example, Loevinsohn (1994) demonstrated that fewer than half of midlevel managers were able to use the information system even to identify best- and worst-performing districts. Nonetheless, if managers use the information, and if improved efficiency and coverage with interventions is the result, the HIS becomes exceedingly cost-effective.

Information will "allow the public, their elected representatives, or donors to determine whether they are obtaining value for money" (Cibulskis and Hiawalyer 2002; see also Mackay 1998). Providing full access to the media will help to accelerate expectations of evidence-based decision making and accountability. Civil society, including nongovernmental organizations, should be the principal users of information to create and sustain citizen demand for quality services. The Healthy Communities Foundation's "dashboard" of lead indicators of health system performance exemplifies one promising example of the visual display of data (http://whatcom.healthycities.org/demo/aboutus.htm). Such dissemination and use of health information has enhanced government accountability for improved health in Papua New Guinea, where reports of local government performance in improving health systems transformed election results (G. Hiawalyer, personal communication).

BENEFITS, COSTS, AND COST-EFFECTIVENESS OF IMPROVED INFORMATION

There is broad agreement that information—plus the knowledge it enables—creates value. Yet it is challenging, indeed, to quantify the added value of information. Information, after all, is necessary but never sufficient to achieve improved outcomes. Other resources—human, material, and financial—are required for change. Nonetheless, it is possible to define the interventions necessary to improve health information and to draw on a few studies to estimate the cost and cost-effectiveness of these investments.

Strengthening of Systems

The steps involved in strengthening HIS include securing funding for a review of the current HIS and planning reforms and then using that plan to secure funding for implementing the reforms. The reforms depend on legislation and regulations that delineate the requirements, incentives, and disincentives for collecting the needed information. Finally, the review of the current HIS includes a situational analysis and outline of a plan that involves a comprehensive information architecture that is linked to both national and international needs.

The HMN Framework includes assessment and planning tools and HIS standards that will guide strengthening of systems. Full implementation will likely take at least 36 months, and the effects on decision making and health outcomes will be detectable only after approximately five years.

Benefits and Effectiveness of Improved Information

The value of health information can be characterized in terms of cost savings; system efficiencies (for example, increased coverage or quality of services); or improved health outcomes

(for example, DALYs saved or improved health equity). Information can also be used to increase overall resources for health. Publications such as this volume, *World Development Report 1993: Investing in Health* (World Bank 1993), and the report of the Commission on Macroeconomics and Health (2000), are important examples of evidence that has been used to change health policies and increase resources for health.

The industrial world holds examples of the use of information to make service provision more effective and efficient. A quality improvement and evidence-based decision assistance program for diabetes patients in the United States created a net savings of US$510,133,[2] primarily by averting hospitalizations (Petrakos 1998). The U.S. Institute of Medicine estimates that a computerized system for managing physician orders for medications costing US$1 million to US$2 million could "pay for itself in three to five years" and prevent injury to hundreds of patients per year (Kohn, Corrigan, and Donaldson 2001).

There are also promising examples of the benefits and effectiveness of improved information from developing countries. Quality improvements driven by better information in Bolivia resulted in a 300 percent increase in hospital utilization rates (Pappaioanou and others 2003). In rural Mali, populations enrolled in a community-based information system calculated delivery costs for childhood immunization to be US$1.47 per child, compared with US$2.79 per child among populations not registered (Zayan, Berggren, and Doumbia 1992).

Better information can also improve efficiencies in the management of pharmaceutical resources. For example, implementing a subnational information system in the Eastern Cape province of South Africa led to improved access to pharmaceuticals, with a 39 percent reduction in stockouts of essential drugs. Such improvements undoubtedly lead to better health outcomes, which may result in increased productivity and consequently an increase in the growth rate of the gross domestic product (Jamison, Sachs, and Wang 2001; Nordhaus 2002).

Costs of Improved Health Information

Few studies have documented the costs of an HIS. Kleinau (2000) estimated the resource requirements for health service statistics, the most expensive of the six subsystems. Using similar assumptions, we have calculated updated costs.

This estimate includes only the public sector facilities, not private sector reporting systems. Reporting from private providers would likely include a more limited set of reported data: diseases, vaccinations, possibly staffing, and minimal utilization. Table 54.2 summarizes the total annual costs and per capita costs of the six health information subsystems.

The costs of a facility-based services statistics subsystem of the HIS (table 54.3) can be assumed in most developing countries to include routine public health surveillance, because these data are obtained at health facilities when ill patients are

Table 54.2 Cost of Essential HIS Subsystems

HIS subsystem	Total cost (US$ million)		Per capita cost (US$)	
	Low income	High income	Low income	High income
Health service statistics	4.8	25.9	0.16	1.66
Public health surveillance (included with health service statistics)	0	0	0	0
Census	7.5	30.0	0.25	1.0
Household surveys	0.6	1.0	0.02	0.03
Vital events surveillance	1.5	6.0	0.05	0.20
Resource tracking	1.5	3.0	0.05	0.10
Total	15.9	65.9	0.53	2.99

Source: Authors.
Note: Table is based on a population of 30 million. Household survey costs are based on the experience of the demographic and health surveys during 2001–2003 (Macro International, personal communication). Costs vary by sample size and by length of the survey instrument; Macro International estimates, an average cost of US$100 per survey participant. A sample of 6,000 is assumed for the low-income setting, and a sample size of 10,000 is assumed for the high-income setting. Cost estimates for vital events monitoring are based on demographic surveillance sites. In the high-income setting, the annual costs are assumed to quadruple. Resource-tracking costs are based on the experience of national health accounts (Abt Associates, personal communication), and the Egyptian Budget Tracking system. Similar costs are estimated for human resources and commodities.

brought for treatment. The additional costs of program-specific surveillance (for example, in support of polio eradication or tetanus elimination programs) could be assumed with a minor marginal investment in addition to facility-based and community-based information systems, including for vital events surveillance.

The calculated range for per capita annual costs of a comprehensive HIS—US$0.53 to US$2.99—compares closely to the estimates from a country setting in which those data have been obtained, including a low-resource country (Tanzania) with a per capita cost of approximately US$0.50 (Rommelmann and others 2004) and a high-resource country (Mexico) with a per capita cost of approximately US$1.00. The Health Metrics Network (HMN) Technical Task Force South Africa has also estimated costs of the HIS at approximately US$26 million (165 million rand) for a population of 43 million, yielding a per capita cost of US$0.60. The highest range of the estimate would apply in countries with higher salaries and a more comprehensive HIS.

Estimations of the Cost-Effectiveness of Interventions to Improve Health Information

The Tanzania Essential Health Interventions Program (TEHIP) is perhaps the best source of evidence for the cost-effectiveness of improved health information. The project was designed to

Table 54.3 Annual Costs of the Facility-Based Services Statistics Subsystem of an HIS

HIS cost	Low-resource setting	High-resource setting
Personnel		
Primary care facility	One person (salary US$4,514/year) spends 10 percent of time at each of 6,000 facilities (US$2,708,400)	Two people (salary US$10,351/year each) spend 20 percent of time at each of 6,000 facilities (US$24,842,400)
First referral level	One person (salary US$4,514/year) spends 25 percent of time at each of 1,000 facilities (US$1,128,500)	Two people (salary US$10,351/year each) spend 75 percent of time at each of 1,000 facilities (US$15,526,500)
District hospital	Two people (salary US$4,514/year each) spend 20 percent of time at each of 300 facilities (US$541,680)	Two people (salary US$10,351/year each) spend 100 percent of time at each of 300 facilities (US$6,210,600)
Regional level	Three people (salary US$10,962/year each) spend 50 percent of time at each of 15 facilities (US$246,645)	Three people (salary US$25,134/year each) spend 100 percent of time at each of 15 facilities (US$1,131,030)
National level	Six people (salary US$10,962/year each) spend 50 percent of time (US$32,886)	Ten people (salary US$25,134/year each) spend 100 percent of time (US$251,340)
Subtotal (personnel)	US$4,658,111	US$47,961,870
Data collection instruments and supplies		
Primary care facility	US$100/year	US$400/year
First referral level	US$250/year	US$1,000/year
District hospital	US$500/year	US$2,000/year
Regional	US$1,500/year	US$5,000/year
National	US$5,000/year	US$30,000/year
Subtotal (supplies)	US$7,350	US$38,400
Information technology: computers and software		
Primary care facility	0	0
First referral level	0	0
District hospital	0	20 percent use of each of two computers with software at US$1,100 at each of 300 facilities (US$132,000)
Regional level	0	Two dedicated computers with software at US$1,100 at each of 15 facilities (US$33,000)
National level	50 percent use of each of four computers with software at US$1,100 (US$2,200)	10 dedicated computers with software at US$1,100 (US$11,100)
Subtotal (information technology)	US$2,200	US$176,100
Training cost	US$180,000	US$1,730,000
Total cost	US$4,847,661	US$49,906,370
Per capita cost	US$0.16	US$1.66

Source: Authors.
Note: Based on a model country with a total population of 30 million.

test how evidence can be used to decentralize health sector planning at the district level and to what extent evidence-based priority setting would result in improved health outcomes. The project budgeted for a marginal investment of US$2.00 per capita for the information and for health interventions, although only US$0.80 per capita was actually spent. The slightly increased investment covered training in the use of the information to set priorities and to better manage the most

cost-effective interventions. The information systems included a district burden-of-disease intervention priority profile, district health accounts, a district cost information system, and district health service mapping. Management and technical support strengthened the district and regional health sector use of the information for management and administration. Communities participated in the ownership and management of health facilities. The cost-effectiveness estimates in this

Box 54.2

The Tanzania Essential Health Interventions Program

TEHIP is a partnership between Tanzania's Ministry of Health and the International Development Research Centre. The project was established to determine the feasibility of an evidence-based approach to health planning at the district level. Testing the premise of the World Bank's (1993) *World Development Report 1993: Investing in Health,* TEHIP enabled district health planners in two of Tanzania's 117 districts to collect and use burden-of-disease and cost-effectiveness data to get the best value for

Source: Authors.

money from national investments in health. Interventions included door-to-door collection of data and training or technical support for managers in the analysis and use of the data for decision making. TEHIP districts allocated services to high-burden diseases, resulting in a tripling of clinic utilization rates and increased treatment effectiveness. With a per capita increase in spending of only US$0.80, district health managers achieved a 47 percent reduction in child mortality rates.

Table 54.4 The Effectiveness of Evidence-Based Resource Allocation in Improving Health

Year	Number of children < 5 years	Probability of dying (birth to 5 years)	Mortality rate (< 5 years)	Total deaths	Deaths averted	DALYs gained/ death	Total DALYs	DALYs discounted at 3 percent
1999	31,000	135.5	34	1,054	—	—	—	—
2000	31,500	119.0	25	791	263	41	10,850	11,511
2001	32,000	110.0	25	803	251	41	10,332	10,643
2002	32,661	114.0	26	853	202	41	8,303	8,304
Total DALYs gained							29,487	30,458

Source: Authors.
Note: 1999 is baseline year; therefore, no deaths were averted.

section are based solely on the declines in mortality of children under five years of age, even though adult mortality also decreased. To ensure a conservative estimate of the costs of the HIS, we used a per capita cost of US$2.00—higher than the actual investment for TEHIP and at the high end of the range of costs for a comprehensive HIS estimated in table 54.2—US$0.53 to US$2.99. All costs were ascribed to the information system, because there were no improvements in the interventions themselves. Expenditures and deaths before 2002 were discounted by 3 percent annually (see box 54.2).

The demographic and epidemiologic data were taken from the Rufiji district, where the most complete data were available. The estimate of the number of children under age five (32,661) is based on the 2002 census results. The Ministry of Health, census, and Rufiji Demographic Surveillance System estimates range from 31,000 to 36,000 children for 2003. Because of this discrepancy, the decline in the total fertility rate, from 5 to 4.7 (5 percent), is taken into account in estimating the number of children less than five years of age for 1999 to 2001. The probability of dying before five years of age declined by 15.6 percent, and because of declining fertility, each year has 1.5 percent

Table 54.5 Costs of Evidence-Based Resource Allocation for Improving Health

Year	Population	Total cost at US$2 per capita (US$)	Discounted cost (US$)
1998	186,809	373,618	420,510
1999	191,012	382,024	417,448
2000	196,515	393,030	416,966
2001	202,176	404,352	416,482
2002	208,000	416,000	416,000
Total costs		1,969,024	2,087,406

Source: Authors.

fewer children than the preceding year. DALYs saved from each child death averted is estimated at 41.2. The resulting calculations of effectiveness are summarized in table 54.4.

The estimates of cost are based on population size projected back from the 2002 census results, assuming an average annual growth rate of 2.8 percent. Costs incurred in 1998 are included because we assume that it takes at least two years (1998 to 2000) of improving the HIS before health benefits accrue.

Cost per DALY saved (US$)
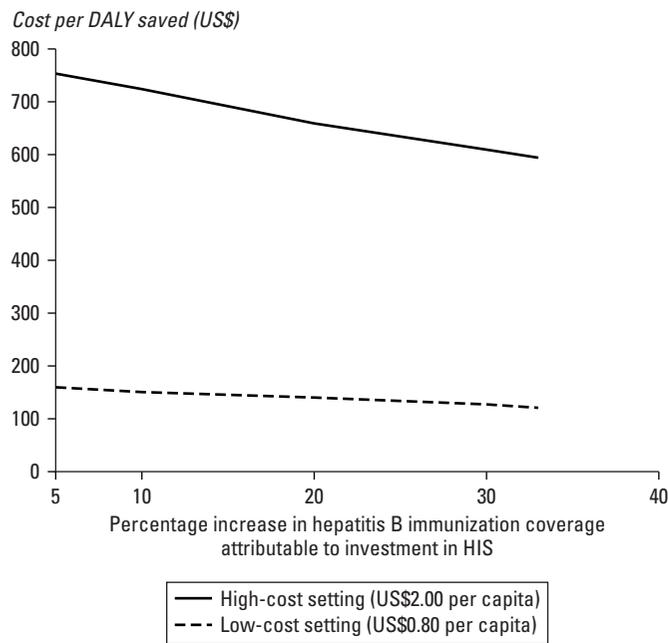
Source: Authors.

Figure 54.1 Cost-Effectiveness of Health Information Systems: Cost per DALY Saved Because of Increases in Coverage Attributable to HIS

Using these figures for effectiveness (table 54.4) and cost (table 54.5), we find that the cost-effectiveness of the HIS that results in improved evidence-based resource allocation and child health may be conservatively estimated at US$68.50 per DALY gained (US$2,087,406 to gain 30,457 DALYs). Even in the poorest countries, this is well below the gross national product (GNP) per capita benchmark for what is considered worthwhile for government investment in health.

This analysis for the TEHIP project is based solely on child deaths averted. But the improvement in health information would also yield substantial benefits for adult populations. For example, HIS-driven increases in coverage with hepatitis B vaccine have varied between 5 and 33 percent (Miller and McCann 2000). These increases in coverage with hepatitis B immunization will result in incremental reductions in death and disability among adults attributable to hepatitis B–induced cirrhosis and liver cancer, thereby averting the loss of substantial numbers of DALYs in low-income countries (World Bank 2002). Hepatitis B vaccine is a cost-effective addition to an existing immunization program, with a cost per death averted of US$11 to US$15 (US$193 to US$262 per DALY saved). But efficiency and coverage can be substantially improved with an additional investment in the HIS. The cost per DALY saved by incremental investment in the HIS can be calculated using estimates of costs of the HIS from table 54.2, plus the estimates of cost and deaths averted because of immunization from Miller and McCann (2000) for populations in all low-income countries (GNP per

capita less than US$997; World Bank 2002). Figure 54.1 shows that, for the high-prevalence countries (Miller and McCann 2000), the investment in a comprehensive HIS is highly cost-effective (US$159 to US$126 per DALY saved for low-cost settings and US$757 to US$597 per DALY saved for high-cost settings), even if the investment results in only minor increases in immunization coverage. A similar analysis for countries with a lower prevalence rate of hepatitis B demonstrates that the cost per DALY saved is higher, but the investment in an HIS still yields a savings of DALYs at a cost that is well below the GNP per capita for the majority of the low-income countries.

These calculations of the cost-effectiveness of investments in an HIS are highly conservative, because they consider health benefits within a single population group (children, in the case of TEHIP) or a single disease problem (hepatitis B). They therefore underestimate the true cost-effectiveness of investment in an HIS, which can drive improvements in program efficiency and effectiveness across a broader range of health interventions.

FINANCING OF IMPROVED HEALTH INFORMATION

The annual per capita cost, estimated earlier, of US$0.53 to US$2.99 for a comprehensive HIS, represents a substantial portion of the current per capita health expenditure for many developing countries. These figures include capital and recurrent costs, although they do not include the costs of any external technical assistance. Because most countries have already made a substantial investment in a HIS, the actual incremental costs to improve the existing HIS likely are much less. Salaries, which account for more than 90 percent of HIS costs, are expenditures that are already being made in most settings, so the marginal cost of HIS improvements would be primarily the initial development costs of planning, training, technical assistance, and information technology upgrades. Furthermore, the costs of HIS improvements may be fully offset or even exceeded by the savings from the resulting improvements in efficiencies in the health care system.

Existing funding is adequate to strengthen systems substantially in all low-income and lower-middle-income countries primarily through the major international initiatives (Global Fund to Fight AIDS, Tuberculosis, and Malaria; President's Emergency Plan for AIDS Relief; and Multi-country AIDS Program of the World Bank). All these funders recommend that 3 to 7 percent of grants and loans be allocated to monitoring and evaluation. Several bilateral development agencies and the multilateral development banks will provide financing for HIS reform, including the U.S. Agency for International Development (USAID) through the MEASURE (Monitoring and Evaluation to Assess and Use Results) Project, which is

designed to improve and institutionalize the collection and use of data for health policy development and program monitoring. The HMN offers some financial assistance to countries that are preparing for and planning HIS reform and will assist countries in negotiating financing packages that blend loan funding with grants from bilateral donors to implement those reforms.

Several international agencies support strengthening systems for national statistics that extend beyond the health sector. STATCAP (Statistical Capacity Building), which is a new lending program offered by the Partnership in Statistics for Development in the 21st Century (PARIS21) through the World Bank, supports the development of national statistical systems. The separate Trust Fund for Statistical Capacity Building offers smaller amounts of grant funding to prepare the statistical master plan that is required for obtaining a STATCAP loan. Although short-term project funding can often be secured for system development, the resulting system and its recurrent costs must be within the country's capacity to sustain it, both technically and financially.

IMPLEMENTATION OF CHANGE: LESSONS OF EXPERIENCE

Underinvestment is the root cause of the nearly universal weaknesses in the HIS in developing countries. This failure is reflected in the poorly paid and undervalued HIS staff; in the irregular and unreliable transmittal of data from the periphery; in the underreporting of events, including births, deaths, and morbidity; and in the failures to base planning and decision making—at both the district and the central levels—on credible evidence (Azubuike and Ehiri 1999).

When the need for HIS improvement is identified, ministries of health should explicitly state the characteristics they need in a reformed system and quantify the expected benefits. A common mistake made in implementing HIS change is failing to recognize the associated need for change in management processes and organizational culture. In contrast, recent HIS reforms in Niger (Mock and others 1993) and Uganda (Gladwin, Dixon, and Wilson 2003) have had unprecedented success because they have been aligned with broader management reforms and changes in organizational culture. Failure to adjust management roles with HIS changes can constrain effectiveness, such as when HIS managers are not given the necessary increased status and authority to demand reports and trigger corrective actions (Gladwin, Dixon, and Wilson 2003). Failure to invest adequately in training, especially in skills for presentation and communication of results, may also inhibit the use of health information. The demand from international organizations and global programs, such as the Expanded Program on Immunization and Stop TB, for reports on vast numbers of indicators has retarded the smooth devel-

opment of the district-level HIS. The HMN will create an alliance of countries committed to a parsimonious consensus technical framework and encourage donors to cooperate with and strengthen the HMN-sanctioned HIS architecture in participating countries.

The predictors of success in developing and maintaining an HIS are as follows:

- high-level commitment to HIS development and the linked changes in management
- a champion of HIS reform who engages the stakeholders and can work across sectors
- an information architecture that is simple, is structured to drive decision making at the level that data are collected, provides incentives and accountability for performance, and links health information subsystems
- investment in training and increased status for the people who manage the HIS.

RESEARCH AND DEVELOPMENT

An effective HIS delivers routine information that enables informed policy making and management but also promotes health research. Routine information systems may serve as a research platform, but the HIS itself should also be a subject of research. Research should drive the continual refinement of HIS methods and tools, thereby ensuring expanding and well-documented returns on our investments in health.

The instruments and methods of the HIS must be continually refined to improve its effectiveness and reduce its costs. For the phased introduction of vital events monitoring, for example, there is a pressing need for the development and validation of methods for projecting subnational results to national rates of birth and death. More research is needed to develop and test new methods for rapid assessment in order to obtain timely and affordable information to solve management problems. As field-appropriate and cost-effective diagnostic technologies are developed, research should be performed to document the utility of obtaining biomarkers in household surveys.

Documenting improved outcomes and lower costs will provide evidence for policy makers on the effectiveness of HIS investments. To better decide how to improve the HIS, decision makers will need documentation of the costs and effects of introducing ICT in support of the HIS. Existing and emerging technologies should be tested for their cost and effectiveness in assisting field-based data capture, instantaneous data transmission, GIS-based mapping of indicators, and compelling presentation for decision making by policy makers, managers, and other stakeholders. Research and development efforts are needed to devise software—or preferably shareware—that is specifically tailored to support the consensus technical framework developed by the HMN.

Bailey and Pang (2004) point out the need for more research in the developing world to better understand users' information needs. In fact, research is needed to better document the entire information value chain, with special attention to improving the identification of information needs, to overcoming the natural disincentives to information sharing, and to enabling better use of information for constructive change. At present, there is still a need to improve the access to information and knowledge in the developing world. However, the future will bring the larger challenge of improving the management and use of information and the knowledge such information can bring. Research in the HIS will be instrumental in both accelerating equitable access to information and improving the management and use of knowledge for improved health.

CONCLUSIONS

More than ever before, it is in the mutual interest of the developing and industrial worlds to invest in strengthening systems for collection and management of health information (Stansfield 2005).

The trend toward "basket" funding for health and sector-wide approaches makes the need for priority setting all the more acute. Priority setting depends on accurate information. The success of efforts to reduce poverty and health inequity will depend on the existence of information systems to detect those problems, facilitate the design of solutions, and track progress toward eliminating the problems. Countries and donors must, therefore, accelerate and harmonize their investments in information systems.

Within countries, the trend toward decentralization of authority for management of health resources has led to further challenges for the HIS, as well as to greater reliance on the information it provides to inform decision making. It is clear from the instructive failures of underresourced systems that the accuracy and value of information reported to the national level will depend on that information's perceived value in the periphery. Information is relevant only if it is used to solve a local problem or if it helps to generate innovation that solves a local problem (Bailey and Pang 2004). Therefore, the decentralization of authority will be successful only with better information systems to support decisions at the periphery, and evidence-based decision making will be possible only if authority can be devolved to the periphery. This decentralization, along with increasing cooperation and collaboration across sectors to improve health outcomes, makes it all the more critical to present data in simpler ways that are understandable and compelling to a broader and nontechnical audience.

Although historically neglected, investments in comprehensive development of the HIS will clearly deliver good value for money. Improvements in the HIS can accelerate broad improvements in health if they are engineered to reflect, reinforce, and even drive health sector reforms. Even more compellingly, investments in the HIS can make health the "thin edge of the wedge," giving governments and politicians a positive experience with information sharing and overcoming the natural disincentives to transparency and accountability. HIS investments hold the promise, therefore, not only of transforming public health, but also of accelerating progress toward good governance in every sector.

NOTES

1. Sauerborn and Lippeveld (2000) have defined a *health information system* as the "set of components and procedures organized with the objective of generating information that will improve health management decisions at all levels of the health system."

2. The dollar amounts given are quoted from the references and are not adjusted for current dollar value.

REFERENCES

AbonZahr, C., and T. Boerma. 2005. "Health Information Systems: The Foundations of Public Health." *Bulletin of the World Health Organization* 83 (8): 578–83.

Abt Associates. 2003. *Primer for Policymakers—Understanding National Health Accounts: The Methodology and Implementation Process.* Bethesda, MD: Partners for Health Reform*plus* Project, Abt Associates.

Azubuike, M. C., and J. E. Ehiri. 1999. "Health Information Systems in Developing Countries: Benefits, Problems, and Prospects." *Journal of the Royal Society for the Promotion of Health* 119 (3): 180–84.

Bailey, C., and T. Pang. 2004. "Health Information for All by 2015?" *Lancet* 364 (9430): 223–24.

Boerma, Ties, J., E. Holt, and R. Black. 2001. "Measurement of Biomarkers in Surveys in Developing Countries: Opportunities and Problems." *Population and Development Review* 27 (2): 303–14.

Cibulskis, R. E., and G. Hiawalyer. 2002. "Information Systems for Health Sector Monitoring in Papua New Guinea." *Bulletin of the World Health Organization* 80 (9): 752–58.

Commission on Macroeconomics and Health. 2000.

De, S., T. Dmytraczenko, D. Brinkerhoff, and M. Tien. 2003. *Has Improved Availability of Health Expenditure Data Contributed to Evidence-Based Policymaking? Country Experiences with National Health Accounts.* Technical Report 022. Bethesda, MD: Partners for Health Reform*plus* Project, Abt Associates.

Duran-Arenas, L., C. C. Rivero, S. F. Canton, R. S. Rodriquez, F. Franco, R. W. Luna, and J. Catino. 1998. "The Development of a Quality Information System: A Case Study of Mexico." *Health Policy and Planning* 13 (4): 446–58.

Economic Commission for Africa. 2003. "Workshop on Organization and Management of Statistical Systems." Report on workshop in Addis Ababa, December 8–12. http://www.unstats.un.org/unscl/methods/statorg/workshops/AddisAbaba/presentation_session8b_financing.pdf.

Gladwin, J., R. A. Dixon, and T. D. Wilson. 2003. "Implementing a New Health Management Information System in Uganda." *Health Policy and Planning* 18 (2): 214–24.

Godlee, F., N. Pakenham-Walsh, D. Ncayiyana, B. Cohen, and A. Packer. 2004. "Can We Achieve Health Information for All by 2015?" *Lancet* 364 (9430): 295–300.

Jamison, D. T., J. Sachs, and J. Wang. 2001. "Mortality Changes and Economic Welfare in Sub-Saharan Africa, 1960–2000." Commission on Macroeconomics and Health, Background Paper for Working Group 1, World Health Organization, Geneva.

Jolly, R. 2002. "Statisticians of the World Unite: The Human Development Challenge Awaits." *Journal of Human Development* 3 (2): 263–72.

Kleinau, E. 2000. "Management of Health Information Systems." In *Design and Implementation of Health Information Systems,* ed. T. Lippeveld, R. Sauerborn, and C. Bodart. Geneva: World Health Organization.

Kohn, L., J. Corrigan, and M. Donaldson, eds. 2001. *To Err Is Human: Building a Safer Health System.* Washington, DC: National Academy Press.

Lescano, A. G., M. Ortiz, R. Elgegren, E. Gozzer, E. Saldarriaga, I. Soriano, and others. 2003. "Alerta DISAMAR: Innovative Disease Surveillance in Peru." Paper presented at the American Society of Tropical Medicine and Hygiene, Philadelphia, December 5.

Loevinsohn, B. P. 1994. "Data Utilization and Analytical Skills among Mid-Level Programme Managers in a Developing Country." *International Journal of Epidemiology* 23 (1): 194–200.

Mackay, K. 1998. "Public Sector Performance: The Critical Role of Evaluation." In *Public Sector Performance—The Critical Role of Evaluation: Selected Proceedings of a World Bank Seminar,* ed. K. Mackay, ix–xvi. Washington, DC: World Bank.

McLellan, F. 2001. "Information Technology Can Benefit Developing Countries." *Lancet* 358 (9278): 308.

Miller, M. A., and L. McCann. 2000. "Policy Analysis of the Use of Hepatitis B, *Haemophilus influenzae* type B, Streptococcus Pneumoniae-Conjugate and Rotavirus Vaccines in National Immunization Schedules." *Health Economics* 9: 19–35.

Mock, N., J. Setzer, I. Sliney, G. Hadizatou, and W. Bertrand. 1993. "Development of Information-Based Planning in Niger." *International Journal of Technology Assessment in Health Care* 9 (3): 360–68.

Murray, C. J. L., B. Shengelia, N. Gupta, S. Moussavi, A. Tanjon, and M. Thieren. 2003. "Validity of Reported Vaccination Coverage in 45 Countries." *Lancet* 362 (9389): 1022–27.

Nordhaus, W. 2002. "The Health of Nations: The Contribution of Improved Health to Living Standards." Cowles Foundation Discussion Paper 1355, Yale University, New Haven.

O'Carroll, P. W. 2003. "The Context for Public Health Informatics." In *Public Health Informatics and Information Systems,* ed. P. W. O'Carroll, W. Yasnoff, M. E. Ward, L. H. Ripp, and E. L. Martin. New York: Springer.

PAHO (Pan American Health Organization). 2004. "Ten Year Evaluation of the Regional Core Health Data Initiative." *Epidemiological Bulletin* 25 (3): 1–7.

Pappaioanou, M., M. Malison, K. Wilkens, B. Otto, R. A. Goodman, R. E. Churchill, and others. 2003. "Strengthening Capacity in Developing Countries for Evidence-Based Public Health: The Data for Decision Making Project." *Social Science and Medicine* 57: 1925–37.

PARIS21 (Partnership in Statistics for Development in the 21st Century). 2004. "Meeting the Data Challenge: A Funding Proposal for PARIS21 and the Trust Fund for Statistical Capacity Building for 2004 to 2006." PARIS21, Paris.

Perrin, E. B., W. D. Kalsbeek, and T. M. Scanlan, eds. 2004. *Toward a Health Statistics System for the 21st Century.* Summary of a workshop, Division of Behavioral and Social Sciences and Education, National Research Council and Committee on National Statistics, National Academy of Sciences. Washington, DC: National Academy Press.

Peters, D. H., A. E. Elmendorf, K. Kandola, and G. Chelleraj. 2000. "Benchmarks for Health Expenditures, Services, and Outcomes in Africa during the 1990s." *Bulletin of the World Health Organization* 78 (6): 761–68.

Petrakos, C. 1998. "Finding a Cure: Disease Management Aids the Search for Better Outcomes." *Modern Physician,* September 1, 2004. http://www.modernphysician.com.

Rommelmann, V., P. Setel, Y. Hemed, H. Mponezya, G. Angeles, and T. Boerma. 2004. "Costs and Results of Information Systems for Poverty Monitoring, Health Sector Reform, and Local Government Reform in Tanzania." MEASURE Evaluation, Adult Morbidity and Mortality Project, University of Newcastle upon Tyne, U.K., and University of North Carolina, Chapel Hill.

Sauerborn, R., and T. Lippeveld. 2000. "Why Health Information Systems?" In *Design and Implementation of Health Information Systems,* ed. T. Lippeveld, R. Sauerborn, and C. Bodart. Geneva: World Health Organization.

Stansfield, S. 2005. "Structuring Information Systems to Improve Health." *Bulletin of the World Health Organization* 83 (8): 562.

Thacker, S. B., D. F. Stroup, R. G. Parrish, and H. A. Anderson. 1996. "Surveillance in Environmental Public Health: Issues, Systems, and Sources." *American Journal of Public Health* 86 (5): 633–38.

Walsh, J. A., and M. Simonet. 1995. "Data and Data Needs for Health Sector Reform." *Health Policy* 32 (1–3): 295–306.

World Bank. 1993. *World Development Report 1993: Investing in Health.* Washington, DC: World Bank.

———. 2002. *World Development Indicators.* Washington, DC: World Bank.

Zayan, A., W. Berggren, and F. Doumbia. 1992. *The Price of Immunization and the Value of Information.* Westport, CT: Save the Children.