Information and Communications Technology for Sustainable Development

Defining a Global Research Agenda

A Report based on two workshops organized by:
Carnegie Mellon University, Pittsburgh
Indian Institute of Science, Bangalore

Washington, DC, 2003, and Bangalore, 2004

Authors
Rahul Tongia, Carnegie Mellon University
Eswaran Subrahmanian, Carnegie Mellon University
V. S. Arunachalam, Carnegie Mellon University / Tamil Nadu State Planning Commission

Information and Communications Technology for Sustainable Development

Defining a Global Research Agenda

ICT-SD Project Investigators:

USA (Supported by National Science Foundation, World Bank, and the United Nations)
V. S. Arunachalam, Carnegie Mellon University
Raj Reddy, Carnegie Mellon University
Rahul Tongia, Carnegie Mellon University
Eswaran Subrahmanian, Carnegie Mellon University

India (Supported by Govt. of India through its Ministries, Departments and Agencies)
N. Balakrishnan, Indian Institute of Science

© 2005 Rahul Tongia, Eswaran Subrahmanian, V. S. Arunachalam

ISBN : 81 - 7764 - 839 - X

Allied Publishers Pvt. Ltd.
Jayadeva Hostel Building, 5th Main Road,
Gandhi Nagar, Bangalore - 560 009, India.

“We must look ahead at today's radical changes in technology, not just as forecasters but as actors charged with designing and bringing about a sustainable and acceptable world. New knowledge gives us power for change: for good or ill, for knowledge is neutral. The problems we face go well beyond technology: problems of living in harmony with nature, and most important, living in harmony with each other. Information technology, so closely tied to the properties of the human mind, can give us, if we ask the right questions, the special insights we need to advance these goals.”

Herbert Simon, 1916 – 2001
Nobel Laureate in Economics, 1978

Preface

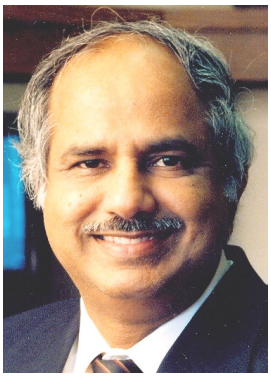
Technology remains as the fountainhead for human development and economic growth. But its spread continues to be painfully slow. Electric power, in spite of its unmatched technical prowess, took almost one hundred years to become commonplace. Even after a century of telephones, billions of people have no access to it. It appears that technological prowess alone is inadequate to guarantee success. Other factors matter: its relevance, availability, affordability, the speed of diffusion, and the social and environmental costs for harnessing it. The development divide we see among and within nations is due to these factors being different across countries, rather than due to technologies per se.

Information and Communications Technology (ICT), with its reach, richness and performance, holds great promise. Is it possible to harness this technology speedily and equitably, learning from the lessons of the past? What are the developmental problems of our society that this technology can address, and does it have all the necessary functionalities and tools or do they have to be developed? What should be the priorities and how can we structure the challenges ahead? These are some of the questions we wanted to discuss in the two workshops we organized in 2003 and 2004.

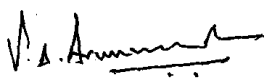
Instead of allowing ICT experts to discuss their wares, we wanted them to first learn the problems of human and economic development. We therefore structured the first workshop in Washington DC with development experts presenting on the challenges in development to scientists and engineers working in ICT. In the second workshop in Bangalore we invited the ICT professionals to work with development experts and identify areas for research, design and deployment of ICT solutions appropriate for sustainable development. Before the second workshop, we also distributed a questionnaire among the participants to know their views and priorities, and, based on their responses, prepared a discussion note to help the deliberations.

This report provides a summary of the proceedings with a few extensions and analyses. It does not attempt to identify all the challenges discussed in the workshops, but is content to provide the highlights and priorities suggested by the participants. These include not only the technological problems but also suggestions for development and deployment of the innovations. We have also summarized the metrics for assessing ICT-enhanced development. Each area suggested at the workshops as worthy of pursuit deserves greater scrutiny than what we have attempted in this report. These will have to be the focus of further studies.

People and governments are becoming increasingly aware that policy innovations and social changes are essential to make technologies work for common good. They are also becoming impatient of the divides that condemn a large fraction of the global population to poverty, undernourishment and disempowerment, and look to technologies such as ICT to eliminate such glaring disparities. This report confirms that ICT can indeed be shaped to become such a tool.



Raj Reddy
Carnegie Mellon
University



V. S. Arunachalam
Carnegie Mellon
University

Acknowledgements and Disclaimers

This Report is the culmination of effort over 24 months by Carnegie Mellon researchers and their associates, with significant contributions from the dozens of international participants in the Workshops. In attendance were participants from over 25 countries, spanning all the regions of world.

Information and Communications Technology (ICT) and Sustainable Development (SD) are themselves vast fields, let alone their intersection, and thus this report does not claim to be exhaustive. We have, however, attempted to capture a broad consensus amongst researchers, development professionals, and decision-makers on the challenges and possible role for ICT in sustainable development.

Support for the Workshops came from the following agencies/organizations:

- US National Science Foundation (NSF) – Grant Number IIS-0303541
- United Nations (UN)
- World Bank (WB)
- Development Gateway
- National Institute of Advanced Studies (NIAS)
- Center for Development of Advanced Computing (CDAC)
- Govt. of India (through its Ministries, Departments and Agencies)
- ICT Industry (Microsoft; IBM; HP Labs (India); Sun Microsystems)

The Workshops and analysis on which this report is based would not have been possible without the help of numerous individuals, including those at various partnering and sponsoring organizations:

Rita Colwell, Peter Freeman, Valerie Gregg, Larry Brandt, Richard Lempert [National Science Foundation]; Nitin Desai, JoAnne DiSano, Kui-Nang Mak, J. Gururaja, Friedrich Soltau [United Nations]; Mohamed Muhsin, Carlos Braga, Jocelyne Albert, Sudhakar Kaveeshwar, Vivek Chaudhry, Reva Eskinazi, Oleg Petrov [World Bank]; K. K. Jaswal (MCIT), S. Ramakrishnan (CDAC), V. S. Ramamurthy (DST), R. Natarajan (AICTE), R. A. Mashelkar (CSIR) [Govt. of India Departments and Agencies]; Raveesh Gupta, P. Anandan [Microsoft]; Uday Shukla, M. Ganesh [IBM]; S. Ramani [HP Labs (India)]; Ganesh Mahabala [Sun Microsystems]; Mark Kamlet, Walt Schearer, M. Bernardine Dias, Anshu Bharadwaj, Shalini Vajjhala, Anita Connelly, Vivian Lee, Helen Higgins, Heather Pons [Carnegie Mellon University]; Tina Joseph, Maitreyee S. Chakravarty, S. Srinivas, S. Swarna, K. Nagarathna, and numerous student volunteers [IISc]; (late) Raja Ramanna, Roddam Narasimha, S. Rajagopal, M. K. Paul, V. A. Joseph [NIAS]; Robin King [Georgetown University]; B. R. Rau [CSTEP], Vidya Natampally, P. Mathur and S. Indira.

In addition, the multitude of participants and questionnaire respondents were integral to this effort, and we acknowledge the contributions of the Workshop presenters, Working Group Chairpersons, and Rapporteurs (details on the presentations can be found in Appendices 3 and 4). We also thank various colleagues and several reviewers for valuable comments, suggestions, and discussions.

Photo credits are to Michael Shamos, Oleg Petrov, V. S. Arunachalam, Swati Save, and Kevin Fall.

Any opinions, findings, conclusions or recommendations expressed in this Report are those of the authors and do not necessarily reflect the views of the sponsoring entities, Workshop participants, or affiliated institutions.

Contents

Executive Summary

Recent global conferences and meetings have brought into focus the unacceptable disparities that exist among nations in human development and economic growth. The poor and undernourished outnumber the healthy and wealthy by billions. The member states of the United Nations have adopted the Millennium Declaration that embodies quantitative goals in many areas of human development, thus providing a roadmap for sustainable development.

Information and Communications Technology (ICT), by its performance and potential, offers numerous options to *help* realize the Millennium Development Goals. Two workshops organized by Carnegie Mellon University, one in Washington, DC, and the other in Bangalore, India, discussed the challenges to development and identified opportunities that ICT provides. The workshops also discussed the technical innovations that are to be realized and the policy options that must be initiated to transform ICT into a veritable tool for sustainable development.

The following findings and recommendations highlight the initiatives required to make the ICT engine drive sustainable development (SD).

1) ***Improve ICT across the 4C dimensions:***

   a) ***Computing:*** ICT is more than computers, and the various thematic areas of sustainable development require innovations in hardware and software for applications such as sensors, controls systems, etc. Computers and other devices must become affordable, and rugged for use without extensive maintenance, security efforts or other specialized skills. They must become easier to use, with interfaces in all local languages, and even in non-text interfaces (pictorial and spoken).

   b) ***Connectivity:*** Developing countries, especially rural areas, typically are without connectivity, let alone broadband (data) connectivity at affordable prices—the "digital divide." Universal access requires new networking and business models, perhaps combining public and private partnerships. ICT is more than connecting to the Internet—human development programs require integration of all forms of ICT and media, such as mobile telephony, TV, radio, etc., as well as interconnecting systems such as sensors, controllers, etc.

   c) ***Content:*** ICT will become relevant to sustainable development (SD) when it provides relevant content (value) to end-users. Often, this would be locally-specific content. One requirement is for tools to make it easier for people to become producers of content and information, instead of just consumers. Ultimately, we would like to achieve the Information Bill of Rights: Getting the right information to the right people in the right timeframe in the right language in the right level of detail. This requires extensive development of appropriate solutions that overcome barriers of language, information complexity, and incompatible or missing structure.

   d) ***(human) Capacity:*** Most people lack an awareness of the potential of ICT, and, beyond technical barriers, many limitations to incorporating ICT are social, cultural, or economic. A first goal for governments must be to increase literacy amongst its populace, especially for the historically disadvantaged, such as women. Often, the success of development projects is driven by complementary (non-ICT) institution building, such as the development of appropriate regulations, legal framework, and supply-chains.

2) ***Success of ICT for SD requires Integration, Scalability, and Sustainability:***

   a) ***ICT can only help achieve development – it is a means and not an end:*** ICT cannot directly achieve the Millennium Development Goals. To be meaningful, ICT needs to be integrated into development as well as engineering and societal systems. Often, proponents or developers place too much focus on raw ICT (or even just connectivity), instead of optimally delivering value and services.

b) ***Active efforts must be undertaken for global inclusiveness:*** Without concerted effort, ICT for SD, like many interventions or projects, would exacerbate existing divides. Solutions must be locally adapted, and extend into rural and other underserved areas. A solution might appear beneficial at a pilot or small scale, but replication and scaling are enormous challenges.

c) ***ICT for SD must be economically viable, and provide value for end-users:*** ICT for SD cannot thrive as a charity—it will become sustainable only when it delivers value. This is not to say that governmental intervention or subsidies have no role, especially during the initial stages. However, markets alone will not drive penetration into underdeveloped regions. The challenge is that the required research and development to make solutions viable can be costly and long-term.

d) ***ICT for SD research must be participatory and collaborative for the solutions to be globally relevant and sustainable:*** The challenges of development are vast, and no single or group of developers can solve all of them. This requires collaboration, sharing experiences, and scaling the programs to make them relevant. Many groups or even smaller countries lack the critical mass for them to undertake the full spectrum of effort required. All stakeholders, including beneficiaries and end-users, must have a voice in assessing its needs, responsibilities, and measures of success.

3) ***ICT for SD must become a recognized and funded enterprise:***

a) ***Bring together all the stakeholders and increase their interactions:*** ICT for SD is an interdisciplinary field and thus requires technologists, social scientists, and development professionals working together. Even within traditional disciplines, ICT for SD must become incorporated into R&D and deployment projects. In the medium and long term, ICT for SD should be categorized as a distinct field with its own defined challenges, support structures, professional societies, peer recognition, etc.

b) ***Develop metrics for success and efficacy, and introduce academic rigor:*** ICT for SD is a nascent field, but attention is often focused on isolated or niche successes. Very few solutions have been impartially assessed as to their claims and still fewer have been verified as to their global validity or scalability. Funding, R&D, and implementation strategies require development of metrics for relevance, effectiveness, scalability, and financial and social sustainability.

c) ***Focus on real innovations and new challenges:*** R&D should focus on real innovations instead of concerning itself with incremental changes to existing solutions, which are often touted as breakthroughs. The required innovations cannot not be just technical, but also in business models and implementation strategies. It is important to identify at least a few “grand challenges” in ICT that can lead to radical innovations in sustainable development. Some suggestions for further research are presented in this report.

d) ***Develop new models for R&D:*** Innovations in ICT that are now available have largely been designed to meet the needs of the developed world. R&D and technology development projects addressed specifically to meet the requirements of developing countries should not be left just to market forces as these markets may not appear lucrative. “Linear” models of R&D lack the feedback loops required to capture economic, social, and cultural compatibility. To help balance technology-push and market-pull, R&D needs to be supplanted by an RD&D (research, development, and demonstration) paradigm, with real-world deployments and testbeds. Such activities should take place in a network of centers and institutions, both in the developing and developed world with contributions from the governments and global organizations. A similar initiative taken some years ago led by the World Bank for forming a strategic alliance of laboratories for agricultural research resulted in significant contributions to developing countries’ agriculture.

1 Introduction – Sustainable Development and ICT

Global development has been unequal, even though the trends in human development are generally positive

We live in a divided world: between rich and poor, healthy and sick, literate and ignorant, democratic and authoritarian, and between empowered and deprived. All the technologies that we developed in the past centuries and all the policies we enacted for enhancing human development have not wiped out these glaring disparities. The numbers are depressing: more than 2 million people (1.5 million in Africa alone) die of tuberculosis annually, for which medical treatment exists; about 2.8 billion people live on less than $2 a day; life expectancy in Sierra Leone is 37, a level not seen for centuries in the West, and, in spite of its protestation of hi-tech, India remains the home for the world's largest number of adult illiterates. We can extract such dismal statistics in many areas of human development, infrastructure availability, economic well-being, environment and empowerment. While many categorizations of countries have been proffered (such as developing, emerging economies, economies in transition, etc.), a new label—a sign of the times—is the "digital divide," which describes the development of countries (and groups within countries) in terms of their capacity to harness the power of Information and Communications Technology (ICT).

Numerous organizations, governmental and non-governmental, public and private, global and very local are working to remove the glaring disparities in development. Some of their efforts are already showing results. The poverty rate, for instance, based on a real income level of $1 per day declined from 29 percent to 23 percent in about twenty years. Infant mortality, due in large part to water-borne diseases and poor hygiene, has fallen from 4.6 million in 1980 to 1.7 million in 1999. It is unnecessary to emphasize that much more needs to be done in all areas of sustainable development, especially in specific areas such as Sub-Saharan Africa and South Asia (Figure 1).

In the following section we discuss the targets for sustainable development (SD) projected at various Global Forums and endorsed either unanimously or by a majority of the nations. While every country has its own set of priorities and targets, and some have appropriated the UN promoted targets as their national ones, we shall base our discussions on the UN promoted ones, for they provide a common template for sustainable development missions. Most sweeping and specific are the Millennium Development Goals (MDGs), which span most facets of human development.

In the subsequent sections of this chapter we outline the rationale for the workshops we organized in Washington, DC, and Bangalore, India, which aimed to identify and recommend relevant options of ICT for sustainable human, social and economic development. While referring to the recommendations of the workshops (Chapters 3 and 4) we shall also discuss the challenges, barriers, and metrics for sustainable development, including where ICT is eminently relevant and can provide useful if not path-breaking options.

Development – Global Targets and Statistics

Over the last 15 years, there have been multiple global meetings on issues of development; we focus on four major UN sponsored meetings and resolutions: Agenda 21, Millennium Development Goals, Johannesburg Summit, and the World Summit on the Information Society (WSIS).

Agenda 21 emanated from the Rio Summit on environment and development, and was a statement of principles for environmental sustainability and development. The program areas that constitute Agenda 21 are described in terms of the bases for action, objectives, activities and means of implementation. The Agenda 21 document runs to forty chapters including a section on means of implementation. However, Agenda 21 does not set forth targets, instead arguing for dynamic programs that could be suitably prioritized by countries depending on their situations and objectives. Agenda 21 was promoted as an evolutionary document.

The Millennium Declaration was adopted by the member states of the UN in September 2000, and this was followed by the Millennium Development Goals, which were projected as the road map for implementing the Millennium Declaration. We believe the MDGs, summarized below, are important for establishing targets for development (detailed in Appendix 1).

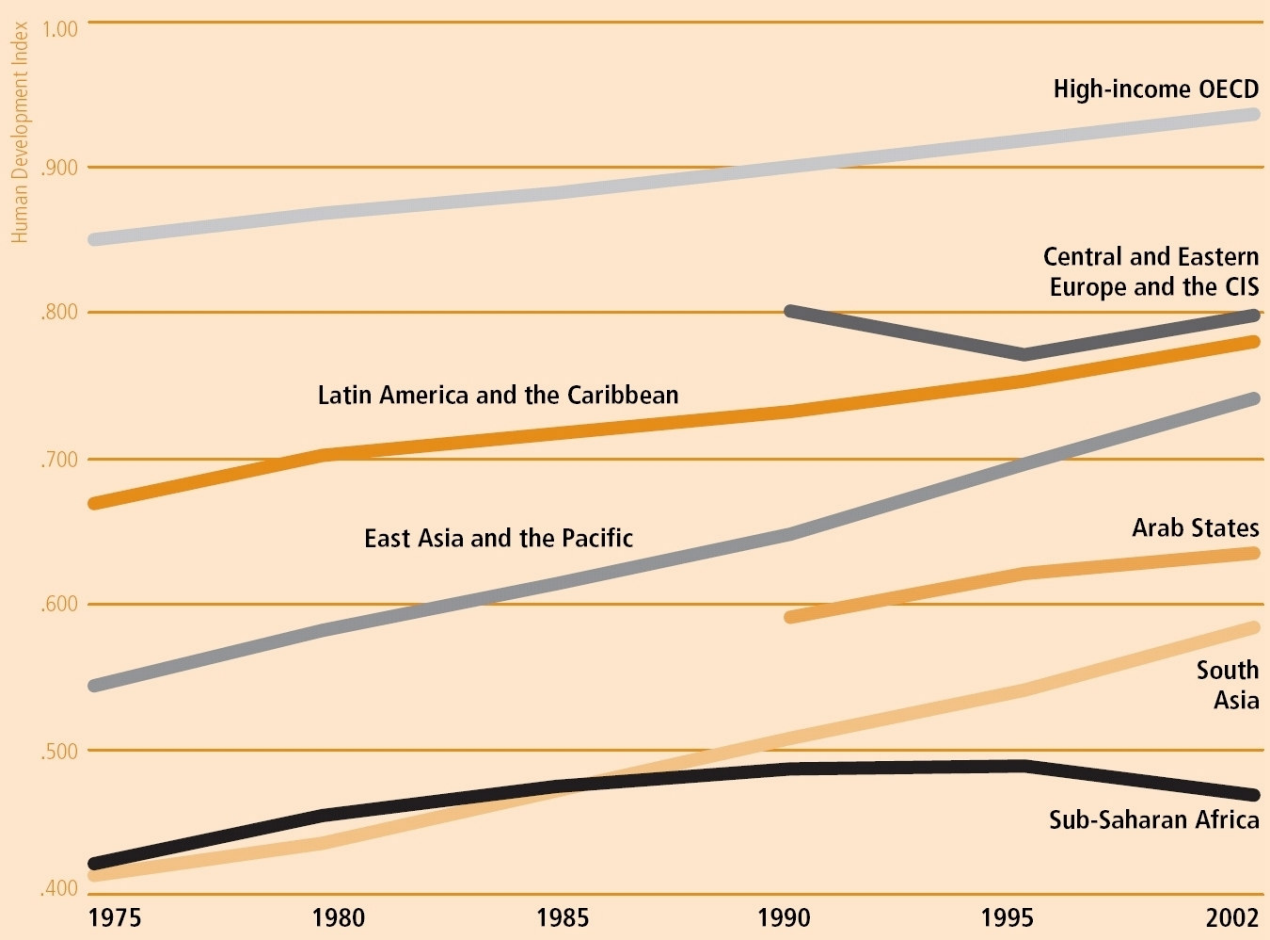
Global development targets are embodied in the Millennium Development Goals (MDGs)

Millennium Development Goals (MDGs):

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria, and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

The Johannesburg World Summit on Sustainable Development (2002) also drew out some of the targets of the Millennium Declaration. However, the scope of the Johannesburg Declaration was more extensive and included many areas of deprivation and action points. For instance, the 19th article states “We reaffirm our pledge to place particular focus on, and give priority attention to, the fight against worldwide conditions that pose severe threats to sustainable development of our people, which include chronic hunger, malnutrition, foreign occupation, armed conflict; illicit drug problems; organized crime; corruption; natural disasters, illicit arms trafficking; trafficking in persons; terrorism; intolerance and incitement to racial, ethnic, religious and other hatreds; xenophobia; and endemic, communicable and chronic diseases, in particular HIV/AIDS, malaria and tuberculosis.”

This summit chose to focus on five particular areas, Water, Energy, Health, Agriculture and Biodiversity, known as the WEHAB framework. The Summit also underlined the importance of technology for development such as cost-effective desalination of seawater recycling and renewable energy resources, diversification of energy supplies, advanced energy technologies and even phasing out of subsidies. There was an explicit reference to Information and Communications Technologies for development in Johannesburg. The importance of ICT culminated in the World Summit on the Information Society (WSIS), Phase I of which was held in Geneva in December 2003. Chapter 2 goes into more detail on WSIS.



Source: UNDP Human Development Report 2004

Figure 1: Human Development Index (HDI). HDI is a composite measure measuring quality of life statistics, beyond merely economic (GDP-based) metrics. The disturbing decline in HDI in Sub-Saharan Africa is primarily due to decreasing longevity and health, especially from HIV/AIDS.

Drivers for the ICT-SD Workshops

A few technologies can be classified as all-purpose technologies as their innovations extend over many areas, and these, in turn, become indispensable elements in society's portfolio of development. Over a period, their contributions to economic and human development become impressively large, replacing older and less efficient methods. Their ubiquity makes one wonder how it was possible to manage in the past without accessing such technologies! Electricity is often cited as a typical example of an all-purpose technology. In spite of electricity's obvious advantages, it took almost a century before electric power could become commonplace. Applications from new technologies are faster these days. The diffusion of radio and television was faster than electricity, and that of the Internet is spectacular. Within 35 years of its existence the Internet has some one billion users and its performance has multiplied manifold (and the World Wide Web, practically speaking, is scarcely a decade old). The rapid diffusion of the Internet and new communications technologies such as mobile telephony suggests that innovations from ICT for SD can also be faster than the progression shown by earlier technologies. This may provide society with targeted tools for sustainable development programs. However, much of ICT research is geared towards sophisticated applications of ICT or makes assumptions

about end-users and their capabilities. The workshops, and this report, aim to bring the ICT and developments communities together.

ICT is recognized as an all-purpose enabling tool for development…the debate is not one of "either–or" but of complementarity

ICT is now part of development. "The debate in the 1990s over choosing between ICT and other development imperatives has now shifted from one of tradeoffs to one of complementarity."[1] There are many initiatives, groups, and programs working on ICT for Sustainable Development. The International Telecommunications Union (ITU) has a development group charged with ICT development and increased penetration, and the UN ICT Task Force focuses on many aspects of ICT for SD. The Development Gateway Foundation, supported by the World Bank, is a clearinghouse and repository for vast information on ICT and development. The G8 instituted the Digital Opportunities Task Force (DOT Force) in 2001 to strengthen efforts on ICT and development. ICT4SD's global visibility can be gauged by the public challenge Kofi Annan, the UN Secretary General, made to Silicon Valley and ICT leaders on November 5, 2002 to make ICT relevant for global human development.[2]

This report does not attempt to comprehensively summarize either the state of knowledge in the ICT or the development arenas. Nor does it present case studies on what works and what doesn't. It presents a slice of all of these, with the aim of guiding global research in ICT for sustainable development. It attempts to combine bottom up (needs-based) requirements from various facets of human development to top down (technology-push) solutions.

Structure of the Workshops

The two workshops were structured to bring together the communities of ICT and of development

ICT experts, especially those working at the cutting edge, typically lack awareness of the problems that professionals working in areas of human development encounter (and the converse is also the case). We therefore structured the first workshop in Washington, DC, June 26-27, 2003, to discuss problems of human and social development. About one dozen presentations covered various dimensions of the problem: from agriculture to urban transportation; from health issues to economic growth options for developing countries. In the concluding session it was suggested that before the second workshop in Bangalore, it was essential to identify the more important problems in SD where the use of ICT would be relevant. For this we sent out a specially designed questionnaire to the participants of the two workshops as well as other professionals requesting their problem preferences. On the basis of the responses received and the meetings the organizers had with experts working in these areas, we produced a discussion note for the Bangalore workshop citing areas of human development and suggesting possible ICT options, to help set the agenda.

The Bangalore Workshop focused on Working Group sessions, spanning various themes of human development (Infrastructure, Basic Human Development, Economic Development, and Empowerment and Governance). Appendices 1 and 2 have more details on the respective Workshop Agendas and Participants. There were informal presentations within groups to identify and recommend appropriate ICT challenges. The working groups were also charged with presenting brief summaries of the role for and research needs in ICT. The deliberations at these sessions contributed to the development of an Action Plan for SD. In the following chapters, we summarize and integrate the discussions at various sessions of the two workshops and the proposed Action Plan suggested by the various groups, concluding with a desideratum on where we go from here.

---

1 As quoted from Markle Foundation/Accenture/UNDP in *ICT and MDGs: World Bank Group Perspective*, December 2003.

2 Kofi Annan has also appealed for relevant science to help meet the MDGs, e.g., in an editorial in *Science*, March 7, 2003: A Challenge to the World's Scientists.

2 Information and Communications Technology (ICT)

Overview

The 4Cs of ICT: Computing, Connectivity, Content, and (human) Capacity

Together, ICT is roughly 6.6% of the world's GDP

The International Telecommunications Union (ITU) estimates the worldwide ICT market in 2002 was almost $2.1 trillion, which they segmented as Telecom Services (39%), Software and Services (31%), and Hardware (30%). This comes to nearly 6.6% of the Gross World Product. Surprisingly, in developing countries, ICT's share in GDP is not low.

ICT can be considered to be built on the 4 C's – Computing, Communications, Content, and (the often overlooked) human Capacity. The recent World Summit on the Information Society (WSIS) focused extensively on 3 Cs, communications, content, and capacity building, and less so on computers. In truth, computing and other hardware continue to become less and less expensive, especially on a price-performance basis. When considering the use of ICT for development, conventional wisdom is that even if hardware is free (e.g., donated), communications, software, and training make ICT expensive.

ICT is more than computers and telephony – ICT is embedded in virtually all industrial, commercial, and services systems

ICT is much more than computers and the Internet or even telephony, even though the digital divide and issues of Internet governance were much of the focus of WSIS. Applications of ICT can be divided under two broad categories. The first are those largely dependent on traditional telecommunications networks (including the Internet) that enable on-demand communications to provide information tailored to the user's convenience and needs. How that information is processed, whether it is used at all, and whether it is transformed into knowledge is left to the human user who asked for that information in the first place. The second group of ICT applications, for want of a more appropriate name, we shall call Human Independent, where information is processed and decisions are arrived on the basis of preset criteria without human intervention at the time of decision making. These can be nearly passive systems, or part of a larger system (embedded ICT). Examples include sensor-based networks that determine automated climate control for buildings today, or, in the near future, sensor networks for malarial larvae detection. Many of the more-discussed applications of ICT for SD are of the first category, ranging from distance education programs, e-commerce, or e-governance, while the second class of applications remains largely unrealized. A major challenge is how to design both ICT and other complex engineering or societal systems such that the two can be integrated.

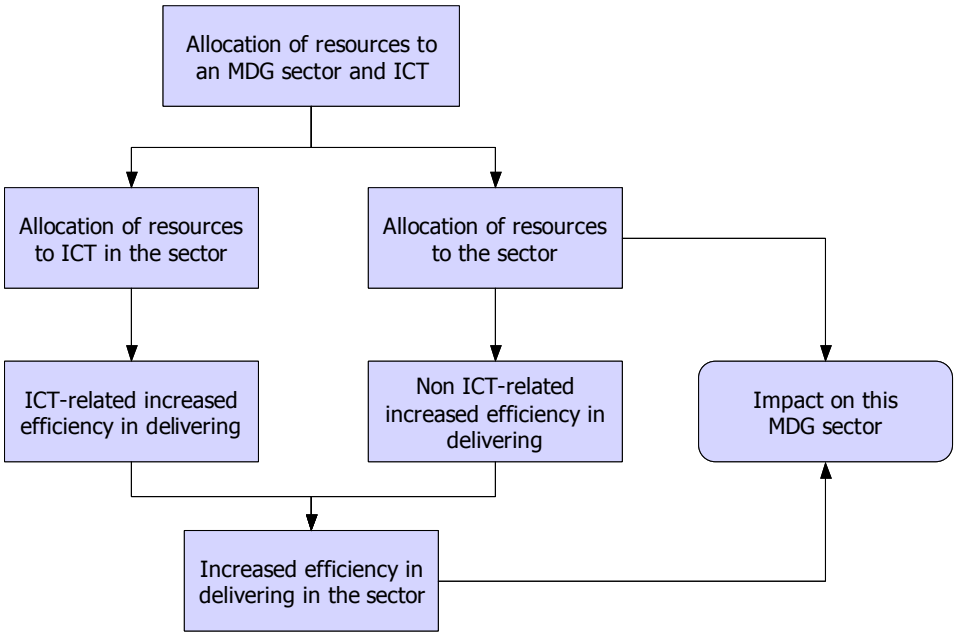
ICT and Development

ICT is a fundamental part of economic growth, especially for the so-termed knowledge economy

Information and Communications Technology (ICT) is viewed as both a means and an end for development. With roughly two-third of the world economy based on services, and the rise of India, Philippines, and other nations as global IT players, many developing countries have accepted ICT as a national mission. Even within manufacturing and industry, ICT has an increasingly important role to play. During 1995 – 2002, when the US economy posted impressive overall growth, nearly one-third of the growth in productivity was attributable to

ICT.[3] While the growth rates of ICT even in developing countries are impressive, the base upon which these apply is very low.

John Daly, in a series of articles,[4] discusses point by point how ICT can work to meet the eight goals identified with the 18 targets set by the MDGs. Similar options are indicated in World Bank publications (such as Footnote 1) and in the World Telecommunication Development Report 2003, excerpted in Table 1.



Source: Lanvin and Qiang (2003)[5]

Figure 2: ICT and Development: Resource Allocation and Impact in MDG Sectors

[3] There are different estimates on the growth and role of ICT, both within ICT sectors and in ICT *consuming* sectors. These estimates are from the *2003 Economic Report of the President*, and are the growth of productivity after 1973-1995 after accounting for cyclical business effects.

[4] http://www.developmentgateway.org//download/222153/JohnDaly-Main.doc

[5] Lanvin and Qiang (2003). *Chapter* Poverty 'E-readication': Using ICT to Meet MDGs: Direct and Indirect Roles of E-Maturity" in Dutta, Lanvin and Paua, ed., *Global IT Report 2003-04* Oxford University Press.

Goal/Target	Role of ICTs
1. Eradicate extreme poverty and hunger Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day Halve, between 1990 and 2015, the proportion of people who suffer from hunger	Increase access to market information and reduce transaction costs for poor farmers and traders Increase efficiency, competitiveness and market access of developing country firms Enhance ability of developing countries to participate in global economy and to exploit comparative advantage in factor costs (particularly skilled labor)
2. Achieve universal primary education Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	Increase supply of trained teachers through ICT-enhanced and distance training of teachers and networks that link teachers to their colleagues Improve the efficiency and effectiveness of education ministries and related bodies through strategic application of technologies and ICT-enabled skill development Broaden availability of quality educational materials/resources through ICTs
3. Promote gender equality and empower women	Deliver educational and literacy programs specifically targeted to poor girls and women using appropriate technologies Influence public opinion on gender equality through information or communication programs using a range of ICTs.
4. Reduce child mortality 5. Improve maternal health 6. Combat HIV/AIDS, malaria, and other diseases Reduce infant and child mortality rates by two-thirds between 1990 and 2015 Reduce maternal mortality rates by three-quarters between 1990 and 2015 Provide access to all who need reproductive health services by 2015	Enhance delivery of basic and in-service training for health workers Increase monitoring and information-sharing on disease and famine Increase access of rural caregivers to specialist support and remote diagnosis Increase access to reproductive health information, including information on AIDS prevention, through locally appropriate content in local languages
7. Ensure environmental sustainability Implement national strategies for sustainable development by 2005 so as to reverse the loss of environmental resources by 2015 Halve, by 2015, the proportion of people without sustainable access to safe drinking water Have achieved, by 2020, a significant improvement in the lives of at least 100 million slum dwellers	Remote sensing technologies and communications networks permit more effective monitoring, resource management, mitigation of environmental risks Increase access to/awareness of sustainable development strategies, in areas such as agriculture, sanitation and water management, mining, etc. Greater transparency and monitoring of environmental abuses/enforcement of environmental regulations Facilitate knowledge exchange and networking among policymakers, practitioners and advocacy groups

Source: Table 4.2, World Telecommunication Development Report 2003 (ITU)
[Reproduced with the kind permission of ITU]

Table 1: How ICTs can help the MDGs

As Table 1 and Figure 2 show, ICT will not directly realize the Millennium Development Goals (MDGs). Rather, its role should be seen best as an enabler, primarily spanning several dimensions: (1) efficiency and competitiveness; (2) new business models and opportunities; and (3) transparency and empowerment.

ICT can help achieve the MDGs by: increasing efficiency, transparency, and competitiveness; opening up new opportunities and business models; and empowering citizens

"Bread or computers?" is often asked as though one could in some way substitute for the other. Admittedly, ICT is not an effortless or inexpensive proposition, but its benefits typically far outweigh the costs, and the scale of investment required is often much lower than that for development (such as providing electricity or water and sanitation). "The issue is whether we accept that the poor should, in addition to the existing deprivation of income, food and health service, etc., also be further deprived of new opportunities to improve their livelihood." (Weigel and Waldburger, 2004)[6]

ICT's value towards the MDGs is in gathering, storing, and analyzing information with greater and greater accuracy and granularity. This enables tailoring development efforts to suit specific social, economic, gender, age, and geographic conditions and requirements.

If we consider the success of development projects and initiatives, both ICT-based and otherwise, in addition to the obvious issue of financing, political economy issues (including legal framework/rule of law, sanctity of contracts, labor and other regulations, etc.) are equally or sometimes more important.

WSIS

The World Summit on the Information Society (WSIS) Phase I brought to the forefront the role of ICT for development. Organized by the United Nations in conjunction with the International Telecommunications Union (ITU), this Summit emphasized the growing relevance of ICT in the global domain. Phase I was attended by more than 11,000 participants from 175 countries, and Phase II will be held in Tunisia in November 2005.

WSIS Phase I Targets largely deal with ICT infrastructure

A summary of the development targets for 2015 emerging out of WSIS is given below:

1. to connect villages with ICTs and establish community access points;
2. to connect universities, colleges, secondary schools and primary schools with ICTs;
3. to connect scientific and research centers with ICTs;
4. to connect public libraries, cultural centers, museums, post offices and archives with ICTs;
5. to connect health centers and hospitals with ICTs;
6. to connect all local and central government departments and establish websites and email addresses;
7. to adapt all primary and secondary school curricula to meet the challenges of the Information Society, taking into account national circumstances;
8. to ensure that all of the world's population have access to television and radio services;
9. to encourage the development of content and to put in place technical conditions in order to facilitate the presence and use of all world languages on the Internet;
10. to ensure that more than half the world's inhabitants have access to ICTs within their reach.

Interestingly, these targets deal primarily with ICT infrastructure.

---

[6] Weigel, Gerolf and Waldburger, Daniele (editors). "ICT4D – Connecting People for a Better World. Lessons, Innovations and Perspectives of Information and Communication Technologies in Development." Swiss Agency for Development and Cooperation (SDC) and Global Knowledge Partnership (GKP). Berne, Switzerland. 2004.

There were several issues of contention and debate at WSIS Phase I

Based on official, analyst, and online reports, there were several major issues and points of contention at WSIS, including:

- Who Pays for Bridging the Digital Divide?
- Use of Open Source Software
- Intellectual Property Rights
- Freedom of Information and Rights of Individuals (balanced with security needs and concerns)
- Internet Governance and Control

There was also a parallel declaration by civil society representatives at WSIS on ICT for development.[7]

WSIS Targets – Can they be met?

If we consider some of the targets from WSIS, one of them is the connection of all the villages in the world (for some basic level of shared access). As per the *World Telecommunication Development Report 2003: Access Indicators for the Information Society*, there are an estimated 1.5 million villages that remain unconnected. If it costs, say, $3,000 per village to connect (assuming we don't simply use a satellite uplink, which could be done for less capital investment) and include other hardware like a PC, then the capital costs would be under $5 billion. Spread over 5 years, this implies a billion dollars per year (and substantially less if alternative but less scalable designs are used). Using soft loans and amortized over a longer horizon, the cost would be only a few hundred million dollars per year (plus operating costs). With standardization and R&D, this cost could fall further. In contrast, providing *subsistence* electricity connectivity, albeit at a household level, requires *billions* of dollars per annum for over 25 years, or at least an order of magnitude more.

ICT and Developing Countries

The history of the Internet is part of the reason for the skew in connectivity between developed and developing countries

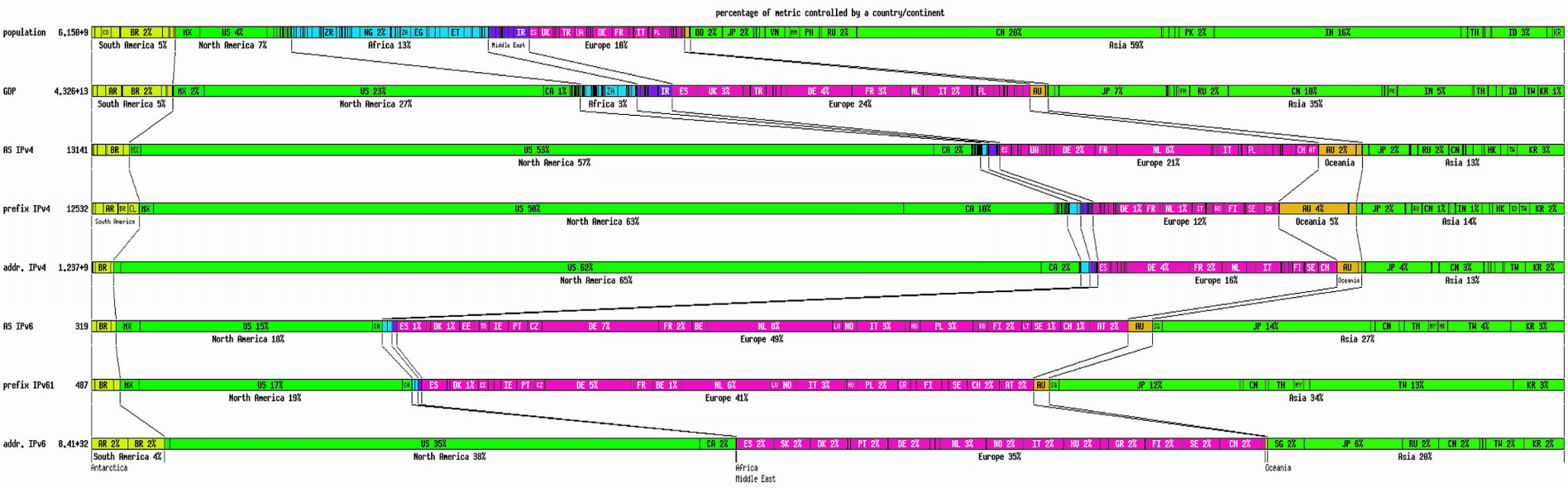
The birth and the growth of the Internet were in the United States, and this has led, in part, to large distortions in connectivity between the developed and developing nations. However, economics remains the obvious overarching reason for the continuation of the divide. Data from the Cooperative Association for Internet Data Analysis (CAIDA) show that the Internet is overwhelmingly concentrated in a few locations (Figure 3). An exception is the East Asian developing countries, notably S. Korea and China. In the last few years, these countries have been aggressively building next generation networks using the next generation of Internet Protocol, IPv6.

Much of this divide is due to legacy reasons, and locations of hosts and users. A consequence of this is the dominating use of English language in the Internet, with content largely hosted in the United States.[8] This has profound implications on not only network design, but also on economics. International connectivity is a major expense and bottleneck for most developing countries. In some countries, even a few megabits of connectivity costs hundreds of thousands of dollars annually! Most trans-oceanic optical fibers interconnect only at specific locations in developing countries, and the capacity is largely used for voice communications, which is more lucrative and commercially predictable.

---

[7] http://www.worldsummit2003.de/download_en/WSIS-CS-Decl-08Dec2003-eng.rtf

[8] Content delivery networks, such as Akamai, and caching are helping reduce this issue, but not all content is amenable for such processing.



Source: CAIDA (2003)

Figure 3: Global Statistics on Internet Based on Routeviews. One notable exception to North American dominance is for the next generation of IP addressing and routing, IPv6. Autonomous Systems (AS) and prefixes are measures of number of networks as announced across the global Internet.

Image provided by CAIDA at the University of California, San Diego under the Cooperative Association for Internet Data Analysis (CAIDA) project under grant NSF proposal ANI-0221172. All rights reserved by the University of California.

Measuring ICT

Most measures of ICT deal with infrastructure, or indirect measures of user capacity, such as literacy

Content is especially difficult to measure

Data and statistics on ICT abound, but some of these lack transparency and standardization. Most popular metrics are based on weighted sub-metrics spanning various facets of ICT, and very few are global (often due to data limitations). The Global Information Technology Report (GITR) ranks 82 economies according to a Networked Readiness Index (NRI), which measures the "degree of preparation of a nation or community to participate in and benefit from ICT developments."[9] The UNCTAD ICT Development Index (2003) uses a Gini Coefficient equivalent to measure ICT distribution inequality.[10] To provide updated and standardized data, the International Telecommunications Union (ITU) published the World Telecommunication Development Report 2003 in December 2003. [11] However, like most reports, the emphasis is on connectivity. It is difficult to measure some aspects of ICT, such as content, let alone its quality or relevance.

This report proposes a new Digital Access Index (DAI), a transparent metric encompassing numerous factors including Infrastructure, Affordability, Knowledge, Use, and Quality. It establishes explicit benchmarks (such as literacy rates, total international uplinking bandwidth[12] etc.) as part of the components, and computes the DAI number for a country, based on which these can be ranked as High, Upper, Medium, and Low DAI nations. We notice a few surprises in the data (Appendix 2), e.g., S. Korea is 4th ranked in the world. Our analysis shows the exceptionally low costs for data connectivity in Korea and Japan – especially on a per megabit/second basis – are not just due to technology and design (densely populated urban areas) but also because of increased domestic content. This reduces a major cost element for Internet Service Providers (ISPs), viz., international connectivity or "uplinking."

The data on the cost of *basic* Internet access (including any applicable local phone charges) as a fraction of Gross National Income (GNI) are instructive. We notice that in many African nations access costs are well over 100% of the average annual per capita GNI! A detailed analysis shows this is not only due to low earnings. The absolute cost of Internet access is very high, due to technology choices/design, limited economies of scale, policy issues such as licensing fees for ISPs, high uplinking costs, and local phone calls charges. For example, in India the hourly phone charges are several times higher than the ISP charges for dial-up connectivity.

We require new ICT measurements that capture the relationship to the thematic areas of sustainable development

Based on the ITU report, an estimated one-third of the world has never made a phone call, and only one tenth have used the Internet. In spite of this deprivation, according to the Telecommunication Development Report, over 80% of the world's population has theoretical access to telephony, e.g., fall under a mobile provider's footprint. Even developing countries have about two-thirds coverage (*excluding* China and India, who reportedly have over 85% coverage by population). The question then becomes not one of availability, but of affordability and perceived need for access.

---

9 Dutta, Lanvin and Paua eds., 'Global IT Report 2003-04' Oxford University Press (2003).

10 Footnote 48 on page 72 describes Gini Coefficients.

11 http://www.itu.int/ITU-D/ict/publications/wtdr_03/

12 The US ranks poorly in terms of total international bandwidth per capita because most content US users need is available domestically. A new metric should be developed that captures location of Internet content, which is linked to the language of the users.

The above measurements of ICT are not adequate when it comes to planning for sustainable development initiatives. More detailed and in-depth measurements addressing each area of sustainable development where ICT could make an impact would have to be undertaken.

Continual March of ICT

The annual price-performance improvement of ICT is dramatic, and expected to continue for many years

In 1965, Gordon Moore (of Intel) predicted that computing power would double every 18 months. This was based not on theory but on empirical extrapolation, and "Moore's Law" has essentially been validated for decades since.[13] Indeed, today's scientific calculator selling for less than $50 has more computational power than the systems used to land an astronaut on the moon. More impressively, when we factor improvements in storage, optics, and wireless technologies, the price-performance curve for ICT looks even more dramatic. As per IBM reports, the annual growth rates of hard disk storage (per square inch) accelerated over the 1990s from ~60% to approximately 100%, and annual memory growth rate is also ~40%. Optical networking is growing yet faster ("Gilder's Law"), and transmission capabilities have been doubling in roughly 9 months, sometimes even faster.

All these improvements in technology have resulted not only in enhanced capabilities, but also in dramatically bringing down the costs. Consider, for instance, wireless technologies. When 802.11 (wireless LAN) devices were originally created (before the WiFi standard), the speed was only 2 megabits per second (Mbps), and the costs were in the thousand-dollar range. Now, variants of 802.11 run as fast as 108 Mbps, and are orders of magnitude cheaper (Table 2). This dramatic improvement came about because of standards and volume. Similarly, there is volume available in the global marketplace for new technologies, but only if fragmentation of technology standards across countries can be overcome.

	Cost Per Node ($)*
1997	800
1999	400
2000	200
2001	100
2002	50
2003	20

Compiled from various sources

* These costs are for the electronics including packaging and power supply, but exclude any external antennae or towers.

Table 2: Wireless Costs Trends – The example of the 802.11 Standard

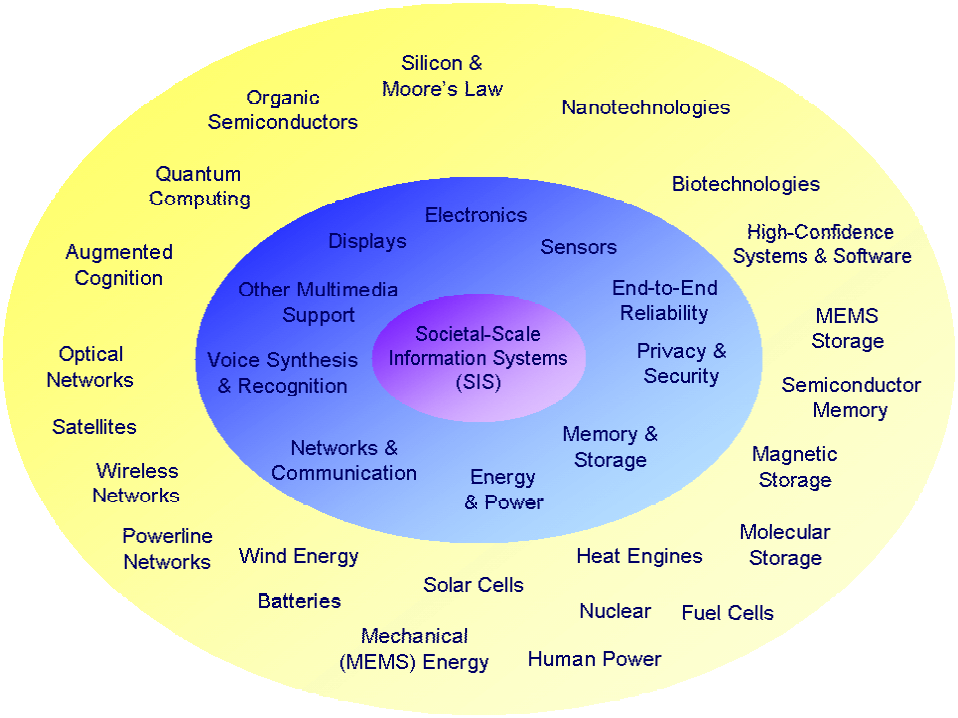
Does this imply that to make ICT affordable, we need just to wait? Halfway, and interim solutions that are incomplete can cause great harm, creating legacy requirements and vested interests. A thoughtful, forward-looking technology roadmap and new solutions are required. There remain a number of questions regarding technology evolution, especially for developing countries. For example, is a standardized, multi-purpose device/processor the ideal solution, or are simpler and cheaper specialized chips better? The answers will depend as much on technology as social acceptance and training, and would vary with the application at hand.

[13] The original paper was not directly related to computing power doubling in 18 months, but transistors per chip, which he saw doubling every 12 months.

Technology Mapping to Development Needs

Many applications of ICT for developing regions today are "trickle-down" instead of purposely developed

There are a number of hypotheses as to why ICT is not yet integrally relevant for development. In his Keynote Address at Bangalore, Richard Newton stated that most ICT for development is simply "trickle down" from the West. This is problematic for a number of reasons: the products are expensive as the intended markets are in the West and these also assume non-trivial user capabilities (literacy if not e-literacy), and almost all require support networks. Even electricity for operating the devices may not be available to a significant fraction of the world's poor. Any viable solution for developing countries will therefore involve sizeable investment in R&D, ranging from enabling technologies to applications (Figure 4).



Source: Bangalore Workshop Keynote, Newton (2004)

Figure 4: Components of Societal-Scale Information Systems. Innovation is required in numerous complementary technologies, such as power systems, biotechnology, etc.

We present a generalized model for ICT and the R&D needs to making ICT relevant for development (Table 3). This is different from the overall 4C framework of ICT (Computers, Communications, Content, and human Capacity) as this is entirely within the technology domain.

Sensors (S)	Acquire and convert observations into information in digital formats
Communication (C)	Reach and richness of networks
Databases / Information Systems (DB/IS)	Global databases of information spanning all media Availability of information in appropriate formats, language and specifications Creating knowledge and contextual bases and algorithms for processes and decision-making
Controllers / Actuators / Effectors (CTRL)	Effecting change (feedback) in nature and the operating domain
Human-Computer Interaction (HCI)	Managing and Interfacing with ICT (Includes new devices for ICT-handhelds, all-in-one devices, etc.)

Table 3: Generalized ICT Model. The domains of ICT span different functionality and segments of any solution.

Fig. 5 shows examples where ICT could make major impact on various areas of human and economic development.

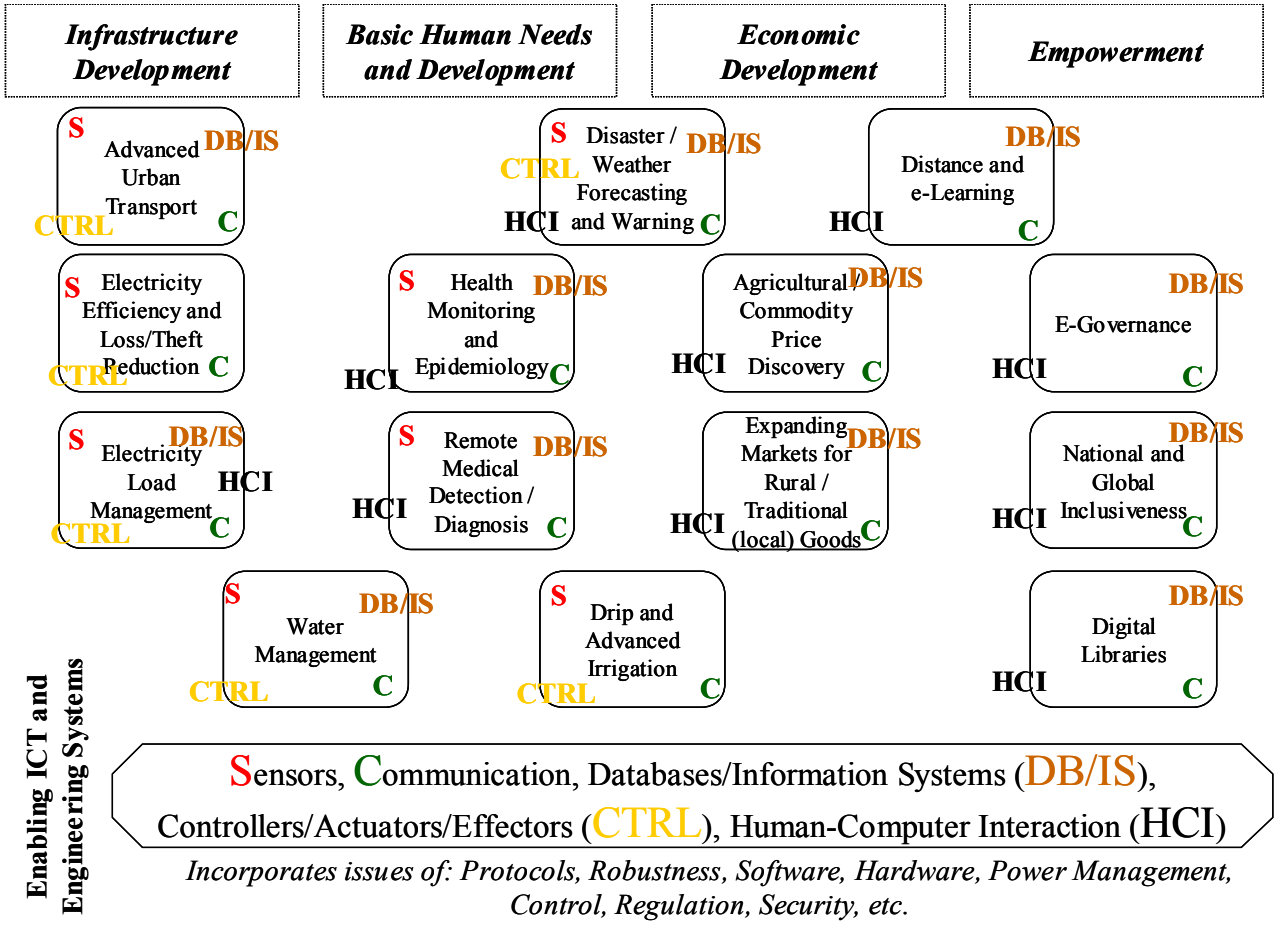


Figure 5: Select Examples of End-use Needs Driving ICT. Shown are the primary ICT components as per the generalized model (Table 3), but almost all components play a role in any real-world system.

ICT Challenges

The simplified model of ICT (Table 3) masks the challenges that require extensive research, both in technology and in the social sciences. We list below several issues that determine the viability of ICT for sustainable development, primarily focused on traditional computing and connectivity. Some of these are common to the needs of developed countries as well, but they often have institutions and mechanisms to address some of these issues.

Digital Divides – Awareness, Availability, Accessibility, and Affordability

The digital divide is actually a manifestation of other underlying divides, spanning economic, social, geographic, gender, and other divides.[14] Attempting to address the digital divide as a cause instead of a symptom of other divides has led to many failures of ICT driven development projects.

The Digital Divide is more than differences in availability of hardware and connectivity

The above four interrelated features determine the value of ICT for a user:

1. **Awareness** – People must know what can be done with ICT; they must also be open to using ICT
2. **Availability** – ICT must be offered within reasonable proximity, with appropriate hardware/software
3. **Accessibility** – relates to the ability to use the ICT (spanning literacy, e-literacy, language, interfaces, etc.)
4. **Affordability** – All ICT usage together should, ideally, be only a few percent of one's income (under 10% maximum on average); this covers life-cycle costs (termed total costs of ownership – TCO), spanning hardware, software, connectivity, education, etc.

Reducing the divide requires improvements across all the dimensions of ICT [dubbed the 4C Framework]: Computing, Connectivity, Content, and human Capacity.

1. **Computing** – PCs are prohibitively expensive for most people, and shared access (e.g., community centers or cybercafes) becomes inevitable. PCs today are very difficult to use, and even "experts" spend a lot of time maintaining their machines, worrying about upgrades, security, compatibility of hardware, etc. As a complementary technology, non-PC devices are an important option, e.g., mobile phones.
2. **Connectivity** – While mobile telephony is improving worldwide (witness in Africa it is now twice the number of landlines), it remains expensive, limited in rural areas, and poor at providing data connectivity.
3. **Content** – Meaningful content is lacking in many languages, and most content is not locally relevant. Today's systems tend to make people passive consumers of information, instead of enabling generation of local information. In addition, rich content demands multimedia (useful to overcome literacy issues), which, in turn, requires broadband connectivity.
4. (human) **Capacity** – Users need to be aware, literate, and innovative to harness the power of ICT. They also should be empowered to use ICT, both by society and by the state.

[14] *Sustainable ICT for Emerging Economies: Mythology and Reality of the Digital Divide Problem – A Discussion Note (*2004). Raj Reddy, V. S. Arunachalam, Rahul Tongia, Eswaran Subrahmanian, and N. Balakrishnan.

Of course, ICT usage does not occur in a vacuum, rather within social and cultural norms that also shape the divide. In addition, ICT usage is based on policy and business models, especially regulation. In the long run, ICT must provide value and be sustainable from both a user and a provider perspective. Affordability is a limiting factor, since we have seen that many people *could* avail of ICT but do not. As the Markle Foundation's Report (2003) on *National Strategies of "ICT for Development"* states, "Digital Divides are not just the result of economic differences in access to technologies (*Have's* vs. *Have-Not's*), but also in cultural capacity and political will to apply these technologies for development impact (*Do's* vs. *Do-Not's*)."[15]

Access is a severe bottleneck for increased ICT use. For many human development projects using ICT (e.g., the case of e-*Choupal* discussed in the section on Agriculture), telecommunications (access) costs are the largest component. As the *UN Global E-Government Readiness Report 2004: Towards Access for Opportunity* points out, we need access to reach opportunity.

Access → **Information** → **Knowledge** ↔ **Opportunity**

The linkages between these steps are not linear or unidirectional. Knowledge is an interpreted extension of information that captures relevance and context, and it is tightly coupled with opportunities.

Hardware and Software Cost

Affordability is a prime factor in the digital divide

Until hardware and software costs decrease, ICT may remain beyond the reach of many users. This is especially true as long as a personal computer is required for data access. When developing countries face higher hardware costs, how much of this is due to import duties or other artificial constraints or a lack of local production capabilities?[16] Is there a price point that would make computers affordable? Instead of a computer per se, could a standardized and mass-produced device serve as a computer, TV, telephone, and digital VCR?

While hardware speeds may scale with increase in number of transistors and components on a chip, software scales only with skilled humans. Open source software has the potential for bringing down software costs, but the interface and use has often been difficult for semi- and un-skilled users. In contrast, it is widely used within the Internet's infrastructure, such as the Apache Web Server.

Some countries actively encourage (or even wish to legislatively mandate) the use of Free and Open Source Software (FOSS) in public IT applications. There are debates as to the applicability of open source solutions, and misconceptions about the commercial use of open source software.[17] Is it possible developing economies could produce their own software, including building upon existing source codes for new programs and applications?

Connectivity Costs

[15] http://www.markle.org/downloadable_assets/gdoi_1223.pdf

[16] This excludes issues such as higher maintenance costs or shorter warranties (if at all) in some developing countries.

[17] Steve Weber, "The Success of Open Source" (2004).

We see from recent ITU data that using dial-up to access the Internet can cost more than the average annual GNI in many countries. This implies that a shared access model becomes de riguer for ICT to be affordable (pay as you use). While many worry about basic access (i.e., dial-up), we contend that broadband should be the target for developing countries because of the higher bandwidth rich applications and interfaces require. Broadband represents even bigger disparity in prices. Per bit, broadband for consumers in Japan is some 300 times cheaper than in Bangalore, which is considered the Silicon Valley of India!

What Is and Why Broadband?

Broadband is a loosely defined term, with some definitions accepting any speed over dialup (e.g., 128 kbps) as broadband. Other definitions require 256, 640 or even 1,544 kbps (~1.5 Mbps) to qualify as broadband. Regardless of the exact number, some features that are attractive to users include always on connectivity and, potentially, flat-rate ("all you can eat") pricing. While critics counter that such pricing hurts infrequent users and breeds inefficiency, it has been found that flat-rate pricing encourages innovation and development of applications. Richness of applications is key for enhancing ICT usage, especially when we consider that graphical interfaces, a must for illiterates, require much higher bandwidth than plaintext.

During the WSIS, some analysts questioned the need for broadband for developing countries ("Let them eat megabits" was an article by a leading US academic). This ignored the leapfrog opportunities of newer technologies (ones that could provide the "Triple Play" of services – voice, video, and data) and also ignored the inexorable fall in capital costs. As a reminder of why developing countries *need* bandwidth, consider even basic applications. One of the authors of this report recently connected for their weekly dose of Windows and anti-virus updates. Size: 8.3 megabytes (a medium update). The dial-up: 28.8 kbps. In practice, it took nearly 6 hours, in part due to poor line conditions and disconnects. The cost for that update, about $6 (dial-up and ISP charges in India), is almost a week's median income in India.

Robustness

Telecommunications equipment is designed to have "five 9s" of reliability, 99.999% uptime, or just 5 minutes of downtime per year. However, in developing countries, the reliability of ICT is typically much lower. Often, the component reliability is trumped by failures in electricity, software, or other complementary systems, including limited availability of spares.

For the above and other reasons, manufacturer's reliability figures do not translate in to real-world uptimes. The almost mythical five 9s of reliability imposes significant burden on ICT systems. Given the complete absence of ICT and other infrastructure in many parts of the world, it would not be unreasonable to consider technology solutions that are slightly less robust or have lower functionality *by design* for dramatically lower costs. One example is the use of asynchronous, ad-hoc email systems, such as the DakNet system using a once-per-day bus that stores and forwards email wirelessly when passing by a village.[18] Similarly, Voice over Internet Protocol (VoIP) systems can be less reliable than traditional circuit-switched telephony or offer lower quality, but users should be free to choose from both solutions.

This is not to advocate a loosening of standards and reliability requirements. Indeed, embedded ICT (such as in sensors) has to be failure-resistant and not require any intervention. However, designers should incorporate all modes of failure, inside and outside the system, and innovate accordingly. In particular, feature sets, reliability, availability, and universal access require trade-offs, and must be defined in context.

[18] DakNet: Rethinking Connectivity in Developing Nations, *IEEE Computer Outlook*, Jan 2004

Content

Much of the content today is not in local languages, or directly useful for most people

Content and applications drive demand for ICT. Today, virtually all applications and most of the content are produced by or geared towards Western users or urban elites. Jaime Carbonell envisaged a Bill of Rights for the Information Era[19] in 1997: "Providing the right information to the right people in the right language in the right timeframe in the right level of detail." To this we can add: for the right cost.

Not only are issues such as literacy and the multitude of languages yet to be addressed, there are also concerns over control of data, accuracy, and transaction costs. In addition, most content is not locally relevant or actionable. In fact, today's ICT systems are largely geared towards passive consumption of information, instead of active production of information and content. Non-ICT knowledge networks in rural areas are often peer-to-peer, and it is therefore necessary to develop tools to enable people to share information better, combining local knowledge with experts and ICT-enhancements.

Many ICT initiatives for development are geared towards professionals, e.g., UN/WHO's Health InterNetwork, and do not normally address the ultimate end-users. In agriculture, the UN Food and Agricultural Organization (FAO) is undertaking several initiatives to address rural information, such as FarmNet, but such global bodies do not have the reach or the mandate to create scaled ICT networks for rural users.

Achieving the above Information Bill of Rights thus requires extensive changes in how we control, create, store, index, search, manage, verify, and disseminate information. It also requires extensive technological improvements in searching, summarizing, translating, and managing content, which will increasingly be audio and video (multimedia) content.

Restrictions on access to information are another policy challenge, in addition to the view by many policy-makers that much of the online content is societally inappropriate (like pornography) or frivolous (like music downloads or video games). This impacts their willingness to use public funds for ICT infrastructure development.

Usability and Interface

Usability challenges represent a major barrier to widespread diffusion of ICT

The primary means of interfacing with data has been the computer, which assumes a certain level of literacy, both lingual and technical. Until local language and graphical interfaces are improved, users will primarily be the upper socio-economic strata or developed nation users.

Though much has been said about user interface for those across the digital divide, greater attention needs to be paid to making hardware and software easier to use for even the more sophisticated user. Today, most users worry incessantly about upgrades, patches, drivers, crashes, compatibility, etc. This excludes issues of viruses, spam, etc., which are discussed under "Security" below. There are some well known examples such as automobiles where the industry has learnt to transform complex technologies into user-friendly systems. We need similar innovations in computer-communication systems.

[19] CMU Language Technologies Institute presentation, 1997

Security

Security is a concern even for uninformed or unaware end-users – it places an implicit cost on all transactions

From end-user perspectives, issues of privacy, trust and verifiability are key concerns. Email was the first "killer application" of the Internet, followed many years later by the World Wide Web. Spam (unwanted email) is now the bulk of transmitted email, and, coupled with viruses, makes going online an ordeal. These also make going online an expensive proposition for developing country users who pay higher usage charges—typically over a slow dial-up. Estimates for the cost of spam vary significantly, but are on the order of 10 billion dollars per year.

Information security, and its aspects encompassing integrity, confidentiality, privacy, and assurance, is a major concern for all countries, including the developed ones. Because they lack institutions to tackle cybersecurity, a few developing countries have become victims of and also launching pads for a number of attacks. To improve domestic cyber-security, countries should develop domestic or at least regional Computer Emergency Response Teams (CERTs). CMU houses the CERT coordination center, and has assisted in establishing a number of such Teams around the world.

Can a global standard on acceptable and non-acceptable use of computers and networks be agreed to? What should the norm be for so-called "white hat hackers" or "ethical hackers?" Legislation is the first step towards cybersecurity, and countries should establish laws allowing the sanctity of digital signatures (and encryption) if e-commerce and online transactions are to flourish. InfoDev has released a useful guide relating to developing countries, the Information Technology Security Handbook (2004).[20]

Developing countries spend only modest amounts on information security, as they do on all areas of ICT. Many analysts also feel that they typically overallocate funding for capital expenditures compared to spending for operations and maintenance, a concern in other areas outside ICT as well.

An added concern is the physical security of equipment and systems in the field. Even copper cables are often dug out, and resold on the market. Optical fibers are less valuable for thieves, once they understand they have no resale value; wireless bypasses this issue to a large extent.

Internet Control, Architecture and Addressing

One of the major debates ongoing in the ICT and development community is over Internet Governance. This was raised at WSIS, and in March 2004 the UN ICT Task Force held the first of several special meetings on Internet Governance, which was addressed by Kofi Annan. Most Internet professionals, including Dr. Vint Cerf,[21] were of the view that the current model of governance is through participation and open standards, and, contrary to popular belief, does not give final say to the US government. The current system might have shortcomings, but handing over Internet management to the UN/ITU was not widely recommended. Instead of scrapping the present system they recommend increasing participation from developing countries. One issue that was raised was the limited funding available for such activities, including traveling to the regular standards and oversight meetings.

---

[20] http://www.infodev-security.net/

[21] Dr. Cerf and Dr. Robert Kahn were the co-inventors of TCP/IP, one of the fundamental protocols of the Internet.

From a practical perspective, developing countries face a lack of physical (Internet Protocol) address space, in addition to issues of Internet name space. The current version of Internet Protocol, IPv4, has been unevenly distributed between nations. CMU/Pittsburgh Supercomputing Center, at least until recently, controlled more address space than all of India! The present constraints require technological fixes such as address translation, which impose operational burdens on operators. One proposed solution is IPv6, the next generation of Internet Protocol, which has enough address spaces for the entire world, and enough for all devices that may eventually get connected. Developing countries should consider embracing IPv6 while balancing legacy and interoperational requirements. Japan and China have been leading the push for IPv6, and developing countries could consider joining such initiatives. In addition to address space issues, the Domain Name Service (DNS) protocol[22] is English-centric, or at least limited to ASCII characters. To enhance foreign language usage, developing countries are pushing for wider adoption of Internationalized Domain Names (IDNs), which are based on Unicode characters.

Another aspect of Internet design affects developing countries not by design, but by their size. An overwhelming majority of international traffic heads to the US or other developed countries. Larger "backbone" or "Tier 1" carriers, who often also host the data, typically demand transit as well as peering charges. In contrast, when trading traffic with each other, they often do private peering under a mutual barter-like system, at no cost. Thus, traffic to *or* from a developing country costs the developing country Internet Service Provider (ISP). On the other hand, in the telephony world, settlement charges actually earn money for the developing countries, especially as they receive more calls from the developed countries than they generate. Solutions to reduce international data connectivity costs include enhancing local content, local storage and data centers, caching traffic and aggregating traffic to increase bargaining power. There also remain unresolved issues regarding transitioning to IP based telephony from traditional telephony.

Internet Governance is closely linked to what we want the Internet to do

Some changes may be required to make it more inclusive, reliable, and responsive to users' needs

The history of the Internet sheds some light regarding the problems faced by users, both in developing as well as developed countries. Technologically, the Internet was built to be "best-effort" and security, quality of service, etc. have been continual add-ons. The Internet was built for simpler uses, and assumed literacy, affluence, and trust amongst end-users. Today, the move is to run everything over the Internet, including voice, video, and even mission-critical applications. Ultimately, Internet governance and protocols both need to be enhanced to expand its ubiquity and inclusiveness. The Internet of the future must be:[23]

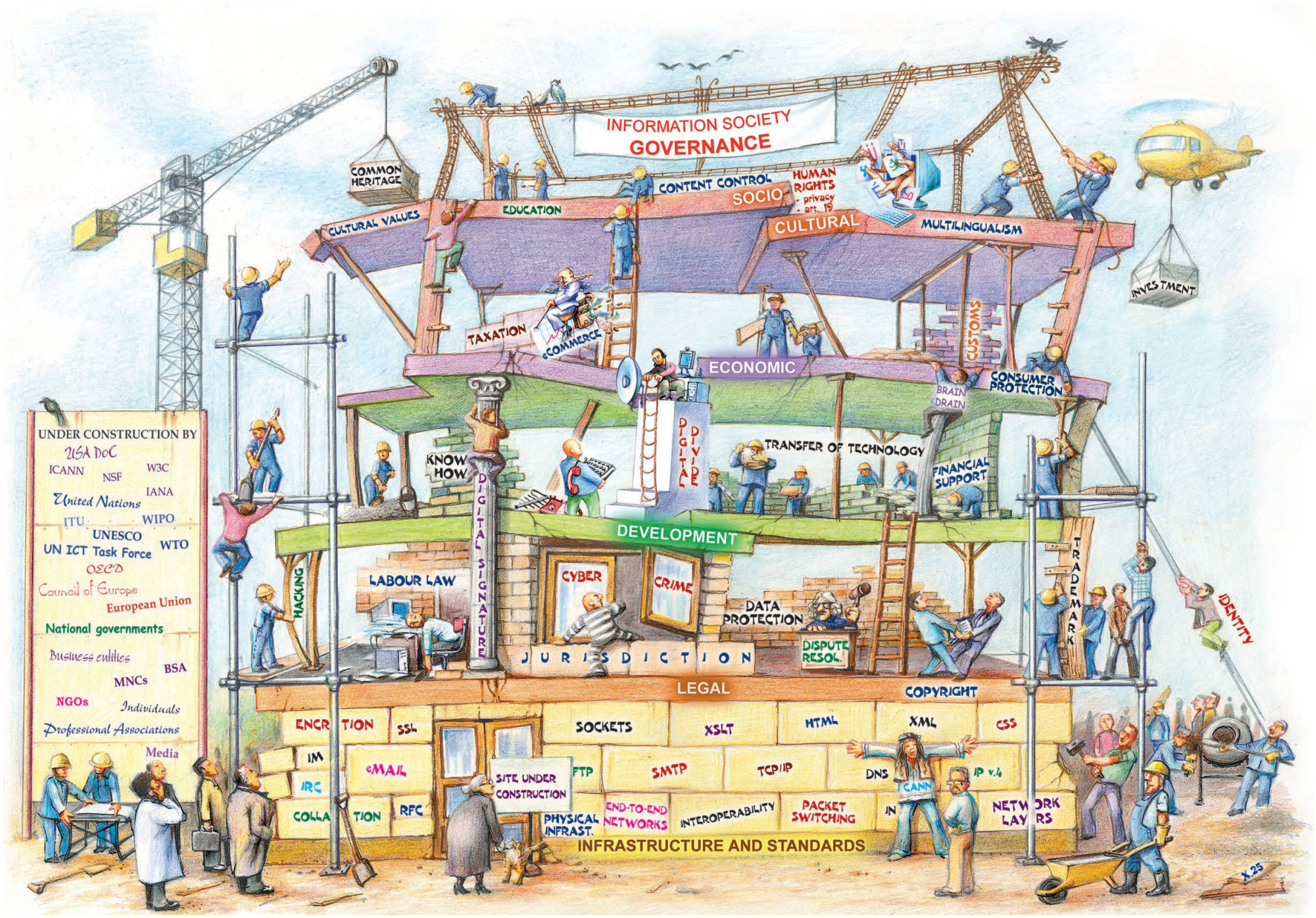
- trustworthy
- reliable
- globally inclusive
- vendor neutral
- easy to use
- affordable
- able to change rapidly
- innovative and capable of significant expansion
- transparently and well managed

[22] DNS maps textual Internet addresses (e.g., www.cmu.edu to the numeric addresses used by networking equipment (in this case, to IP address 128.2.11.43).

[23] "Internet Analysis Report – 2004 – Protocols and Governance." Internet Mark 2 Project (2004).

Today's structure of Internet governance largely does not include issues relating accountability (spam, fraud, etc.), and various stakeholders (ranging from technical bodies like the Internet Engineering Task Force—IETF—to the UN/ITU) are struggling to define roles and responsibilities (Figure 6). The current manager of Internet registries, the International Corporation for Assigned Names and Numbers (ICANN, which has a contract with the US Dept. of Commerce), states that "… issues of concern to Internet users, such as the rules for financial transactions, Internet content control, unsolicited commercial email (spam), and data protection are outside the range of ICANN's mission of technical coordination."[24]

[24] ICANN website, 2005.



Source: Information Society Library [Reproduced with permission]; Graphic by Baldi, Gelbstein and Kurbalija

Figure 6: Internet Governance and the World Information Society – Under Construction

Regulation and Policy

Competition has overwhelmingly helped consumers in the telecom world, but many developing countries regulate ICT restrictively. Incumbent telecom providers in developing countries are often Government companies or PTTs, and are relatively slow to adopt new technologies. They have also opposed certain disruptive technologies, such as voice over Internet Protocol (VoIP), unlicensed wireless (Table 4), etc. There are additional burdens on ICT providers such as ISP licensing fees, import duties on equipment, and restrictions on services.

	Developed countries	Developing countries
% with license exempt wireless spectrum	96%	41%
% with license exempt wireless devices	95%	40%
% with license exempt wireless commerce	65%	20%

Source: The Wireless Internet Opportunity for Developing Countries (2003)

Table 4: Policy Divide on Unlicensed Spectrum and Usage. There have been some improvements over time, but the general trends remain the same.

Government policies drive technology adoption, innovation, and investments

Countries with fewer restrictions often find higher levels of ICT adoption

Convergence is an accepted evolution of telecom systems, bridging voice and data, fixed and mobile. Historically these have been regulated as separate services, despite being able to operate largely on common infrastructure. The forthcoming ENUM standard, which bridges IP address with traditional telephony numbers, is designed to facilitate such convergence. However, there remain contentious issues over ENUM regulation and directories, especially at an international level—developing countries as well as smaller service providers don't want ENUM directories or registration to become another source of institutionalized competitive advantage in the hands of a few.

Numerous studies have shown that cost reductions for users have come not from technology per se, but through competition. Nonetheless, competition within the data side of ICT is less well understood, and even the US is grappling with such issues (such as Open Access rules). An aspect of regulation that has been finessed in the Internet world is that of Universal Service Obligations. Mechanisms for universal service, both for access itself and for VoIP users, need to be devised.

Fundamentally, many national ICT strategies should focus more on users and capacity building than getting lost in technical issues. To succeed and be sustainable, ICT initiatives should go beyond top-down or centralized (governmental) initiatives to encompass the many stakeholders and participants. In fact, many listed successes have come from efforts that involve cross-sectoral collaboration from the four key sectors: government, business, researchers in labs and universities, and civil society organizations.[25]

When considering policy issues, legislation (or lack thereof) is an important factor when companies consider investing in ICT. Issues that require governmental clarity include those of jurisdiction, taxation, and culpability/liability. It is especially vital to separate the roles, responsibilities, and liabilities of end-users versus content providers versus service or bandwidth providers—if an end-user sends an email violating national standards, should the ISP be held accountable?

[25] Ernest Wilson, various publications.

Wireless

Wireless access technologies hold great promise for developing regions given low usage densities and limited legacy (wireline) deployment

Wireless has grown dramatically in the last decade, e.g., mobile phones outnumber traditional landlines by 2:1 in Africa.[26] Wireless technologies offer a compelling solution for access requirements in the developing world, especially in light of the lower density of users. In particular, unlicensed spectrum, such as through "WiFi," offers attractive opportunities for fixed broadband wireless access. However, many countries are yet to embrace unlicensed spectrum (Table 4). By and large spectrum is underutilized, even in the developed world.

While newer cellular phones (GPRS and third generation—3G—cellular) offer reasonable data capabilities, the actual usage has been modest at best in most developing countries.[27] In contrast, SMS (short message service) has become quite popular for transmitting information. There are several applications of SMS for rural users, but these are usually based on one-to-one applications. Development of web-interfaced, inexpensive SMS systems with group mode might be a good technique for applications such as agricultural price-discovery, weather forecasting, disaster warning, etc.

The very success of wireless telephony in developing countries poses a paradox for broadband data services. 3G (wireless) services do not have the bandwidth of even modest wired broadband services. Most developed countries use DSL or cable modems for broadband data provision. These were built out using an entrenched base of landline voice users and cable TV subscribers, who are not present in many developing countries.

An additional challenge regarding wireless, telephony, and data networking is *convergence,* which adds numerous regulatory and technical challenges. Technology is evolving faster than regulations.

Wireless – It's more than WiFi

802.11b ("WiFi") has garnered a lot of press and attention, with mushrooming "hotspots" around the world, and it is becoming very cheap (<$20 client node, if not integrated into devices). However, this technology was not designed for the wide area network, and is generally optimal for shorter ranges. A new technology, 802.16 ("WiMax"), is an emerging tailor-made alternative for access needs, and offers the capabilities to work in licensed as well as unlicensed spectrum. In addition, it is expected to work without Line of Sight, which is required for WiFi over long distances.

One technical issue affecting how well such technologies can be used for access is the allowed power emission level. Here, the US (FCC) standards allow greater power than European and many developing countries (ETSI) standards, and FCC standards are also more liberal in allow antenna gain. If developing countries wish to extend the capabilities of wireless technologies, they would need to modify their wireless emission standards appropriately.

In the coming years, we can expect continued improvements in technology, with lower prices, longer ranges, and greater capabilities. Radical changes are expected from technologies such as "smart antennae" and "cognitive radios."

Energy and Power

For truly remote locations, electricity is a greater challenge than ICT, and standalone solutions such as solar power may cost more than a computer and telecommunications

[26] African Telecommunication Indicators 2004, ITU.

[27] The upgrade to 3G services itself faces not only financial difficulties (operators in developed countries vastly overbid for the spectrum) but also a rift in standards and upgrade paths—there are parallels to the GSM vs. CDMA debate.

equipment.[28] Even in grid-connected locations, power availability and quality remain variable, hampering ICT deployment. Low power ICT solutions are required, especially for remote usage.

Availability of electricity is a critical pre-requisite for ICT; the alternative of standalone solutions is very expensive

The need for low power consumption becomes critical when we consider ICT devices that are not computers, such as mobile devices or sensors that can be minuscule. Until technology improves to reduce power consumption, the size and cost of these devices will remain high, and their penetration low. One of the areas of active research is in wireless mesh networks, which can offer significant energy savings. The transmission energy increases with the square of the distance, so if we put an intermediate node halfway (adding a hop, and thus, some delay), we can cut power requirements per node by a factor of four. While twice as many nodes are required, the lower power has profound implications for battery or energy design. The lower radio power emission levels also reduce interference between neighboring nodes, allowing higher throughput.

Digital Information and Broadcasting

In the era of Internet, broadcasting technologies are often ignored. Over the air broadcasting is an extremely cost-effective method of unidirectional imparting of information, e.g., through TV or Radio. Digital Information can be broadcast easily, and there is already widespread usage of digital TV and, now, digital radio. These technologies can carry data signals for various end-use devices, ranging from computers to specialized but less expensive receivers that could receive data on, say, weather, agricultural prices, etc.

The use of digital media reduces the marginal costs of information transmission significantly. As and when analog media shifts to digital, it not only improves the spectrum usage, but makes it more easily compatible with multiple mediums. Through digital radio stations on the Internet, e.g., we can improve content availability in local and regional languages. Digital information brings with it a number of challenges, including Intellectual Property Rights (IPR) and security.

Economic Models, Markets, and Role of ICT

Market-driven models alone will not push ICT into developing regions

Balancing technology push with market pull is a fundamental requirement for harnessing ICT for sustainable development. End-users ultimately drive demand, and when the technology has been presented to them in usable formats and affordable “chunks” (e.g., pay-as-you-use cellular and cybercafes/kiosks), we find its use growing rapidly in developing regions of the world. Users are more likely to visit a cyberkiosk if they can perform multiple types of transactions, sometimes bundled as packaged services. These may or may not require an assistant or intermediary who can, for example, help place an order for fertilizer. In the absence of a viable market, as would be the case for the neediest of the needy, governmental or other external intervention is required to help penetration.

---

[28] If we consider a new desktop PC with CRT monitor and communications, the total peak power consumption can be ~400 watts. If we assume standalone solar systems cost about $5 per peak watt, which is competitive, the power needs cost around $2,000. This would only give power for the equivalent of sunshine hours per day, estimated at 6 hours of usage in many tropical i.e., solar favorable regions. Using batteries to store the power and adding solar panel capacity for non-sunlight periods adds to the costs further. In reality, average power usage is much lower than peak power usage, and new technologies such as liquid crystal display (LCD) monitors cut down power consumption significantly. Nonetheless, energy costs are a significant operating cost (when available from the grid), or capital cost for standalone power.

There are no universally accepted models for choosing technologies and timing. While leapfrogging is often touted as a boon for developing countries, e.g., the direct deployment of digital cellular instead of analog, there are few in-depth analyses on the cost/benefits of leapfrogging and/or waiting for the appropriate technologies. Sophisticated analysis techniques such as Real Option Theory may help in technology assessment.

Leapfrogging into advanced technologies offers strong potential for cost-effective deployment

The notion of waiting may appear counterproductive, but otherwise there is also a concern that an intermediate or poorly optimized – but readily available – solution will end up costing much more in the long run. India suffered this fate when it went for cross-bar telecom switches in the 1970s, just when digital switches were emerging. Many decisions are also practically irreversible, locking in users as well as providers.

When choosing technologies, people often worry about backwards compatibility and cite that as a reason not to deploy greenfield designs. However, in many developing countries, the installed base is so modest and the growth rates for the near future are so high that the extra cost of compatibility even with a leapfrog technology should be less of a concern. The story is different in developed countries. When London added a single digit to its telephone numbers in the 1990s, citing increased demand for phone lines due to fax and modem lines, the total cost was reported to be over $2 billion!

Other than waiting for ICT to become affordable, there have been only a few specifications suggestions on making ICT affordable for sustainable development. For instance, one can engineer them to be inexpensive, which itself may turn out to be an expensive process. Suppliers can also be pushed by externally imposed performance or functionality standards. It would be difficult to say that a particular technology X has to cost only that much, but one can mandate that a certain device must be capable of specific services, and such a device should not cost more than a certain price. An example can be mobile phones adding enhanced emergency locational services. If there is sufficient demand, suppliers will figure out how to make solutions cheap.

Developing regions are a large but untapped market…but their needs are not necessarily the same as in developed regions

Studies by Prahalad and others indicate the 4 billion people at the Bottom Of the Pyramid (BOP) collectively form an enormous and untapped market—who today often overpay for their goods and services, but in smaller volumes.[29] The challenge is encouraging innovations if the expectation will be for reduced producer margins (commoditization); this is especially the case for hardware.

One hypothesis presented by Richard Newton at the Bangalore Workshop is that there are many ICT and development projects that deal with end-users/devices, but few deal with a broad infrastructure. On the other hand, if a nearly ubiquitous (but appropriately scaled and designed) infrastructure were built and available, numerous development projects would be enhanced or even enabled. One major challenge is evaluating an all-enabling solution like ICT whose impact will be spread across a number of dimensions, and includes both tangibles and intangibles. Which set(s) of stakeholders should pay for the ICT? In addition, as shown in Figure 2, there remains the additional task of optimizing investments between ICT and the developmental projects.

In addition to the social impact that ICT can generate, its business case can also be sound. Given that nearly 10% of the gross world product is logistics, even a small reduction in that expenditure results in tens or hundreds of billions of dollars in savings. The problem, once again, is on identifying the stakeholder(s) who should pay for such upgrades and services. In addition, the payback period might be long, and development agencies and governments

[29] C. K. Prahalad and Allen Hammond, “Serving the World’s Poor, Profitably.” Harvard Business Review, September 2002.

must be committed to whole-hearted, long-term implementation. The summarizing presentation[30] at the Washington Workshop captured the consensus amongst participants regarding the role of ICT in helping meet the Millennium Development Goals: “ICT is not *the* solution to any of them…ICT is a piece of the solution to all of them.”

[30] Michael Shamos, CMU, Washington Workshop Summary Presentation.

3 Thematic Groups – ICT and Sustainable Development

The two Workshops (Washington, D.C., and Bangalore) focused on ICT and sustainable development, and the discussions were segmented into four broad (and sometimes overlapping) thematic topics, along with several suggested sub-groupings:

1) Infrastructure Development
   a. Energy
   b. Water
   c. Transportation
2) Basic Human Needs and Development
   a. Food
   b. Healthcare
   c. Drinking water
   d. Primary education
3) Economic Growth and Poverty Reduction
   a. Agriculture growth
   b. Higher education
   c. Job creation
   d. e-Commerce
4) Alienation, Empowerment, and Governance
   a. National and International Inclusiveness
   b. Democracy
   c. e-Governance

In addition to overlap and linkage, some issues—such as environmental—cut across individual themes. Given such overlap between some topics, and differences in formats between sessions, this report doesn't strictly adhere to the order or segmentation given above.[31] Preparations for the Bangalore Workshop included a series of questionnaires (Appendix 5) we sent to a number of professionals working in these fields seeking their comments and suggestions on what they see as challenges in the field and how ICT could play a role.

[31] As a large number of Bangalore participants focused on Education, a separate working group on Education was formed, and its recommendations are presented in this report.

Infrastructure Development

Water and Sanitation

Overview

Water is a precious resource with uneven global distribution ... people worry it will be the reason for major global conflicts

Freshwater is necessary for virtually all life on earth. Humans require clean water not only for drinking but also for cooking, personal hygiene, and reducing disease. It is also a vital component of industrial and economic growth, to say nothing of being central to agriculture. The UN Committee on Economic, Social, and Cultural Rights at their 29th Session (11-29 November 2002) brought forth the following declaration: "The human right to water entitles everyone to sufficient, affordable, physically accessible, safe and acceptable water for personal and domestic uses."

Unfortunately, much of the world lacks water and sanitation (Table 5). Target 10 of the MDGs is to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation. Challenges in sanitation are deeper than drinking water, and this affects healthcare, quality of life, and urbanization.

Region	Percentage Within Region Without Access to Improved Water			Percentage Within Region Without Access to Improved Sanitation		
	Urban	Rural	Total	Urban	Rural	Total
Sub-Saharan Africa	17	56	34	27	57	47
Middle East/North Africa	5	23	13	7	30	17
South Asia	6	20	15	33	78	66
East Asia/Pacific	7	33	24	27	65	52
Latin America & Caribbean	6	34	14	14	48	23
CEE/CIS & Baltic States	5	18	9	3	19	9
Industrialized Countries	0	0	0	0	0	0
Developing Countries	8	31	22	23	65	48
Least Developed Countries	18	45	38	29	65	56
World	5	29	18	15	60	39

Source: WHO/UNICEF Joint Monitoring Program, 2001

Table 5: Percentage without Access to Improved Water Supply and Sanitation, by Region (2000 data)

The above table suggests that by 2015, every year an additional 60 million people will need to gain access to drinking water and 120 million people to sanitation! At the current level of investments, there is an annual funding gap of over $100 billion to achieve these targets (Table 6).

(billions of US$)	Current Annual Investments in 2000	Estimated Annual Investments to Achieve Goals	Estimated Annual Funding Gap
Access to drinking water	13.0	13.0	0
Sanitation and hygiene	1.0	17.0	16.0
Municipal waste water treatment	14.0	70.0	56.0
Industrial effluent	7.0	30.0	23.0
Agriculture	32.5	40.0	7.5
Environmental Protection	7.5	10.0	2.5
Total	**75.0**	**180.0**	**105.0**

Source: WHO/UNICEF Joint Monitoring Program, 2001

Table 6: Estimates of Funding Needs for Water and Sanitation in Developing Countries.
Only a fifth of countries appear to be on track to meeting the Water and Sanitation MDG, one of the most difficult of the MDGs.

Not only is there a funding gap, since the mid/late 1990s, investments in international infrastructure projects have dropped dramatically. Water was never a favored investment target for the private sector because of its very poor financial viability. Compared to telecom, the only truly profitable sector in most developing countries, tariffs of gas and power generally do not cover the full costs, and water lies at the extreme, with cost recoveries only on the order of 30%! Thus, this sector requires large upfront and continual public support for its sustenance. In addition, investors face a multitude of risks (similar to all international infrastructure investments) such as currency risk, regulatory risks, sovereignty risks, etc.

A saving feature is that the demand for water is not limitless. There are indications that through technological improvements in consumption and distribution, demand can be stabilized, if not reduced. Even in the US, in spite of its GNP growth and demand for more energy, water usage peaked at the end of the 1970s, and has dropped since then. In absolute numbers, however, US consumption remains far higher than the world average.

Incorporating feedback from participants and questionnaire respondents, we present a summary of the challenges, barriers, and metrics for success in the thematic groups.

Challenges

1) Provide drinking water to the world's population; about 1.5 billion will lack sustainable access by 2015 (under business-as-usual assumptions). This includes the problem of local access nearby, if not in-home
2) Provide improved sanitation access to the world's population; about 2 billion will lack sustainable access by 2015 (under business-as-usual assumptions)
3) Ensure water quality and health standards are met for water consumption
4) Ensure sustainability of water supplies, e.g., without depleting groundwater resources. This might include technologies for reusing and recycling water for different uses
5) Make water available for non-drinking uses, primarily agriculture, but also commercial and other economic uses
6) Improve the efficiency of utilization for non-drinking uses such as agriculture, which accounts for the majority of the consumption
7) Reduce water losses and improve tariff collection

Barriers

1) Water is overwhelmingly subsidized, even in developed countries. The average cost recovery worldwide is estimated to be around 30%. Poor pricing signals can lead to wasteful usage and over-usage. The poor often lack public supply of water, and pay a heavy burden for water gathering
2) Lack of accountability and poor decision-making by public officials. Ignorance of mid- and long-term consequences of decision-making; the short-term view overwhelming long-term planning and investment. Unavailability of data and non-transparency in decision-making
3) The linkages between water, agriculture, healthcare, energy, and economic growth are not well articulated, especially from a planning perspective
4) Planning for water must correlate to the resource base, i.e., the micro and macro watersheds. However, most decision making and even data collection is based on political or other artificial boundaries and, consequently, decisions are not based on sustainable supply
5) Lack of data on water uses, users, alternative supplies, etc., with a temporal and spatial granularity needed for optimal decision-making
6) A system that allows the elite to seek exit strategies that do not scale, e.g., through individual filtering units, tanker supplied water, individual tube wells, etc.

Measures for Success and Failure

1) Reducing the number of persons who lack water and sanitation, especially with reliable data of sufficiently detailed granularity (household, rural/urban, regional, etc.)
2) Defined and achieved metrics on local access to water and sanitation – whether in-home or within a 5 minute walk, etc.
3) Measured improvements in the quality of drinking and discharged water
4) Stabilization or rise in water tables
5) Publicly available data on water resources, reserves, and their quality for local users, who are empowered to seek redress or other interventions as required
6) Improvement in soil conditions for agriculture, especially related to salinity, chemicals, and other issues dependent on water

Role of ICT

ICT can help in the following areas:

- Assess supply adequacy, modeling different supply and technology alternatives, and factor in different usage technologies. This can include the development of dynamic Geographic Information Systems (GIS) for identifying water availability, storage, transmission, and distribution
- Quality monitoring, especially through low-cost sensors. Quality of water impacts healthcare, agriculture and industry
- Optimize the allocation between different uses of water (e.g., treated drinking water, water for industrial usage, agriculture, etc.) via market and non-market mechanisms
- Water use management at a societal level, including distribution systems—which incorporates loss reduction, equity, etc.—and utilization efficiency

To make a meaningful impact, stakeholders must have access to information for informed decision-making, and they must have open access to range of different models and

solutions. ICT can also help with education regarding efficiency, loss reduction, and new technologies. Reducing losses is especially important for expanding water coverage and availability. Many large developing country cities only provide water supply for a few hours per day, and 25 – 50% of the water remains unaccounted for (either lost through poor infrastructure or pilferage).[32]

Examples of Needed Research

1) Low-cost approaches to quality assessment and modeling, including:
   a. Sensors
   b. Data collection (including ad-hoc networks) and sensor integration
   c. Analysis
   d. Dissemination
2) Systems analysis of supply adequacy across a range of uses, technologies, etc., which:
   a. Demands adequate data (e.g., GIS (Geographic Information Systems) based, point-of-use data entry, etc.)
   b. Requires flexible and robust models

Energy

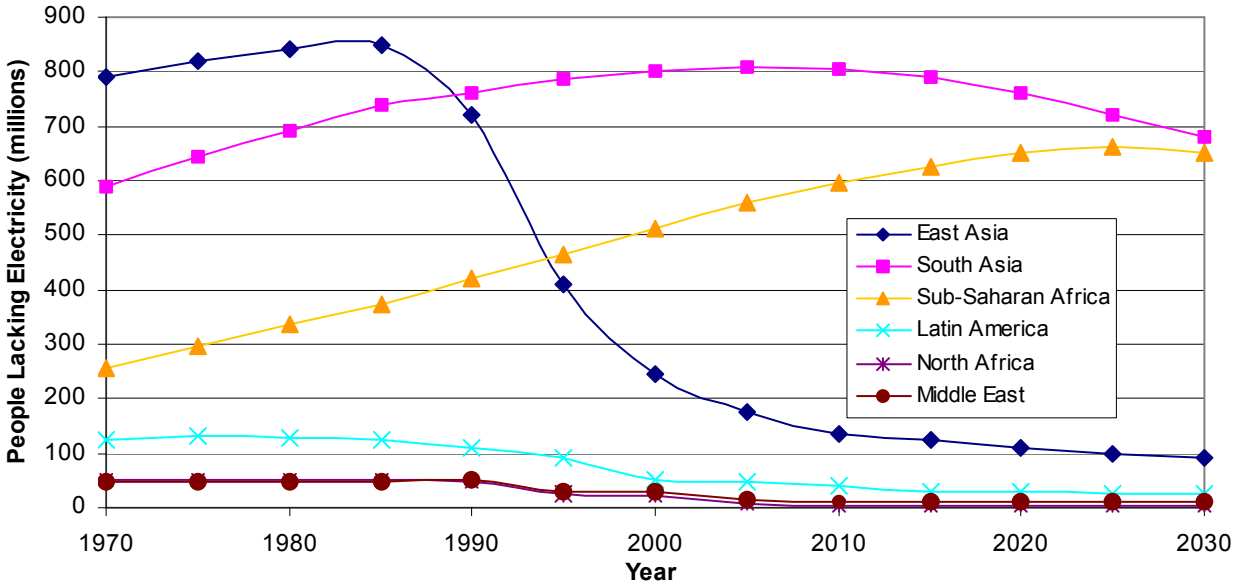
Overview

The linkage between energy use and economic development is well-recognized

Energy use is the engine for development, and its correlation with economic output is well documented. Energy is used in every area of human endeavor, from cooking to manufacturing, from transportation to entertainment. In developing countries, there is a large dependence on non-commercial fuels, such as agricultural and animal wastes, and these do not enter most official statistics on energy consumption. Electricity is a unique form of energy that is clean, amenable for virtually all applications and transportable with appropriate networks. Indeed ICT depends on the availability of electric power. However, there is an acute shortage of reliable electric power in developing countries.

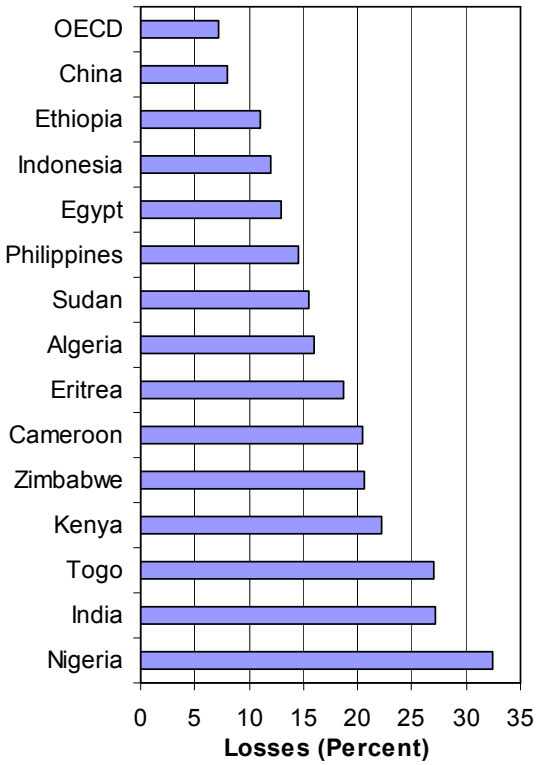
The pattern of electricity consumption in developing countries is very different from the developed ones. For a start, the level of electrification is low (Figure 7), and some two billion people worldwide lack electricity. Consumption varies dramatically, e.g., the annual per capita consumption in India is around 380 kWh compared to the US with annual per capita consumption of over 11,000 kWh! What electricity is available is often intermittent (blackouts and brownouts), and of poor quality. It is generally subsidized, but for some sectors that are economically productive, the prices can be very high. Agriculture can be a large consumer in many developing countries—mainly for pumping underground water—and the losses due to transmission, distribution and theft are also typically very high (Figure 8). In many developing countries, energy industries—as the overall economy—are state-centered. This leads to weak, but rigid, formal institutions including regulatory bodies, courts, and corporate governance, and makes the introduction of innovations difficult. Innovations based on ICT are especially vulnerable as they have the potential to challenge the very established patterns of supply and distribution.

[32] World Development Report 2004 (World Bank)



Source: World Energy Outlook (2002)

Figure 7: People Lacking Electricity. South Asia (largely India) represents the largest absolute share of unelectrified population, but Africa shows slower improvement. A large part of the worldwide gain achieved in the last 20 years came from China, whose electrification grew in parallel with economic growth.



Source: World Development Report 2004, World Bank

Figure 8: Electricity Losses (Select Countries). These losses include both technical as well as theft. Roughly 10% of losses may be largely unavoidable (technical losses, which depend on system design), but the remainder is theft. This is one area where ICT can play a major role – loss reduction.

While much of the discussions focused on the power sector, fuels are also required for heating and cooking. The latter is largely based on biomass in developing countries, though official statistics often do not capture such non-commercial fuels. ICT will be required to adequately quantify energy flows of all types. Given much of the non-electricity energy consumption in the world is for, cooking, transportation and heating, ICT can have a major role to play in consumer education. In addition, it can indirectly help financing and microfinancing plans. It is widely accepted that many small-scale (household or commercial) energy savings investments—such as upgrading insulation—have a high Return on Investment (ROI), but are often not undertaken due to lack of financing or lack of knowledge. ICT can increase the market efficiency and perhaps help create a system for funding energy efficiency and upgrades. This same system would also be beneficial for increasing the penetration of modern energy services, where the payback would also be societal in addition to monetary.

The Workshop discussions explicitly did not factor in carbon dioxide (CO_2) and climate change issues, as participants felt that though this was an important issue, it was not central to developing country needs. While a large fraction of the growth of emissions might occur in developing countries, especially China, the absolute growth and total from the developed countries and Former Soviet Union/Eastern Europe will remain higher for the coming decades.

Challenges

1) Provide energy and electricity services to all households who lack access today; this number is at least several hundred million. Increasing electricity penetration and consumption would also require increasing supply of electricity and generation
2) Increase the use of environmentally appropriate and sustainable fuels, such as renewables
3) Reduce the losses in energy systems, both technical as well as theft. Devise alternative technologies (both supply and consumption) that have higher efficiencies and can enable options such as energy storage, demand side management, etc.
4) Reduce the impact of energy usage on the environment, ranging from locally (down to the home level, e.g., indoor air pollution by cooking using biomass) to globally (CO_2 and greenhouse gases)
5) Provide energy security for users and nations, including price stability/predictability
6) Provide security and environmental safeguards when using fissile (nuclear) materials
7) Develop appropriate adaptation strategies to climate change and sea-level rise, which may impact developing countries disproportionately, in addition to mechanisms for reducing greenhouse gas emissions

Barriers

1) Limited financial resources to help provide commercial energy services, especially electricity. Distortionary pricing of energy, encouraging wasteful usage by many classes of users
2) Poor understanding of linkages between energy and other areas of human and economic development
3) Widespread theft/tampering of electricity and other energy services
4) Conventional wisdom and economies of scale that favors large, centralized power generation plants over decentralized and renewable technologies, which may be more appropriate to rural areas

5) Current technological limits in renewable and storage technologies, with relatively low R&D funding for such options
6) Users unaware of options available for improving their pattern of consumption or unwilling to modify it. Options are also limited due to long life-span of capital stock
7) Limited enforcement of technical and environmental standards
8) Utilities and providers rewarded economically for increased production and sales, and not for energy saving initiatives
9) A system that allows the elite to exit poor supply through the use of decentralized (individual) generation systems such as diesel power generators

Measures for Success and Failure

1) Improving the penetration of modern energy services, measured by households accessing such services. Increased use of energy services for improved quality of life
2) Improving the efficiency of energy consumption with consequent increase in economic output for every unit of energy consumed
3) Consistent improvement in system net availability, including reduction in losses (technical as well as theft)
4) Increased use of sustainable energy sources
5) Improved environmental metrics, varying from local particulate counts to global CO_2 levels
6) Improvements in the availability of quality electricity, measured by voltage profiles, downtimes, faults, safety records, etc.

Role of ICT

The role of ICT can be for:

- Data collection and system level use
  - Metering at all levels (e.g. digital meters that are cheaper than electro-mechanical and can incorporate control and communications)
  - Real time T&D status data
  - Supervisory Control and Data Acquisition (SCADA) systems; new protocols for smart control
  - T&D efficiency and loss reduction
  - Smart control of distributed resources and microgrids
- Resource and needs assessment
  - Viability of alternative market structural arrangements
  - Analysis of network vulnerabilities & interdependencies including during / after extreme events (storms, floods earthquakes) and non-extreme events
  - Search for robust strategies and redundancies
  - Control of loads, load shedding, load management, etc.

Examples of Needed Research

1) Low cost, reliable digital meters, with ICT enhancements such as control and communications
2) Convenient low-cost efficient end-use devices with options for demand management

Transportation

Overview

Transportation needs range from the local to the global, and impact the economy, environment, and quality of life

About half the world's population lives in cities, and rapid urbanization has led to over 300 cities in developing countries of over one million people. By 2015, there are likely to be about 23 megacities with a population of over 10 million. This represents a major challenge for planners. In the Washington Workshop, Nancy Kete presented several examples of large cities in developing countries that have built or are building out advanced public transport networks. These projects have incorporated many advanced technologies such as sensors, communications and GIS, and have had a major impact on urban development and overall city "livability."

Transportation affects not only public safety and healthcare (pollution) but also the quality of life (commuting), economic opportunities, and productivity. Transportation falls under several categories, by mode (bus, car, rail, etc.), ownership (public vs. private), and goods transported along with their characteristics (people, raw materials, finished products, perishables, etc.)

The Workshops focused primarily on two types of transportation, segmented as private and public transportation. While energy usage is part of planning for transportation, it did not form a major part of the transportation deliberations. Nonetheless, such issues are important given the large fraction of energy used for transportation. In particular, the strategically important oil is primarily used for transportation. ICT can have medium to long term benefits on energy reduction through "smart" cars. Today, some 80% of energy in cars is lost as heat, and 18+% is consumed moving the vehicle itself. Only 1-2% is actually spent moving the passenger(s). One improvement from an energy perspective would be to make vehicles lighter. Ironically, marketing and misguided public perceptions of safety are pushing for heavier vehicles. The use of ICT, sensors, and inter-vehicle coordination (such as using technologies based on dynamic cruise control) can allow for lighter vehicles while maintaining or enhancing safety.

Challenges

1) Reduce congestion and overcrowding in all transportation systems and on the roads within cities
2) Improve public transportation systems including affordability, and deploy innovative solutions for meeting both peak and off-peak transportation needs
3) Build safe and efficient rapid transport options between urban centers, including the development of modern port facilities
4) Connect rural areas with urban centers with all-weather roads and other transportation systems. Improve connectivity between areas of greatest demand
5) Improve inland waterway usage for low-cost bulk transportation
6) Improve the environment in urban (and rural) areas, as affected by transportation
7) Increase the safety of transportation systems
8) Improve the sustainability of transportation systems, especially vis-à-vis fuel usage
9) Improve access for those with special needs

Barriers

1) Limited financial resources for public and private transportation

2) Corruption and high transaction costs in public works
3) Poor quality of designs, materials, construction, and maintenance. Lack of enforceable standards for construction and materials. Lack of planning tools and testing centers with authenticated credentials
4) Limited space and ability to effect fundamental redesigns of highways, roads and streets, only allowing for incremental improvements
5) Perceptions and incentives favoring individual transportation options; increased affluence allowing greater individual transportation modes
6) Limited enforcement of existing laws, varying from safety to environmental to encroachment
7) Limited incorporation of externalities into system design and pricing
8) Urban layouts that often relegate the poorest to the most remote or underserved areas
9) Perception that "bigger is safer" when it comes to passenger vehicles
10) Partial improvements negated by signals that encourage further utilization of infrastructure (i.e., more roads bring even more users, including new residents – urbanization)

Measures for Success and Failure

1) Reduced crowding and congestion in public transportation systems and roads
2) Reduction in time spent commuting
3) Improvement in air quality
4) Increase in use of public transportation and ride-sharing options, as well as alternatives such as bicycling, across all socio-economic strata
5) Improvement in passenger transportation per unit energy input
6) Increase in safety and reliability of transportation systems

Role of ICT

Air, Rail, and Bus Transportation (Shared transportation systems)

- Universal access to on line reservations & purchase for public transportation, with real-time information; this must be device/platform independent, e.g., through mobile phones
- Mechanisms for improved safety, fuel monitoring/consumption, etc.
- Optimized use of assets and facilities, including efficient load tracking
- Distributed approaches to rail/air traffic control
    - Can enhance safety and allow greater capacity utilization

Private and Road Transportation

- Transportation planning models
    - Focus on life cycle costs
    - Adequate treatment of mixed vehicle types
- Air quality data collection and advanced air pollution models
- Monitoring of infrastructure conditions, e.g. use of low-cost sensors
- Transparency/clarification of decision authority for ongoing operations
- ICT enabled externality metering, such as congestion pricing (*but* there are equity issues)

Examples of Needed Research

1) GPS based rail traffic control and improved low-cost load tracking (e.g., use of RFIDs[33])
2) Low-cost air quality monitors combined with advanced air pollution models (e.g., including photochemistry)
3) Optimization of public and private transportation based on GIS and the use of innovative options such as congestion monitoring and pricing that integrate urban planning

ICT and Infrastructure – General Observations

The Workshop participants determined a number of commonalities between the infrastructure sectors, and made some observations about the overall role and potential of ICT.

To aid planners and researchers, the Working Group developed a generalized framework for energy, water, etc., with applicability to nearly any resource-based system (with appropriate modifications as necessary). This can be used for even non-infrastructure systems, such as agriculture or labor (Table 7).

Availability / Supply / Production (A)	How much is available, where, when, to whom? Is it in an appropriate form, or does it need processing or conversion?
Transmission and Storage (T)	Where does it flow, with human intervention or naturally? What timeframes and contingency plans are available?
Distribution (D)	This is where end-users receive the resource, and is often the segment with the highest losses, due to poor designs and technical and man-made losses.
Consumption (C)	Affects overall demand and sustainability. Lifetime of capital stock is a barrier to change, but greenfield designs and growth models can allow leapfrogging technologies and solutions. Carefully introduced social changes can modify consumption.

Table 7: Generalized Model for Infrastructure/Resources

ICT can help manage and optimize infrastructure development and natural resources usage

The entire ATDC model above can obviously benefit from ICT, especially with fine granularity and appropriate dissemination of information to the stakeholders. In addition, ICT can help optimize resource utilization, not only saving money but also allowing increasing penetration of infrastructure services.

It is important to recognize that just putting information on the web is often not enough. For a start, how many stakeholders have access to the web, and what opportunities are there for effecting feedback? Increasingly, raw data is being made available to outsiders, which can aid analysis and accuracy. However, even the raw data is subject to assumptions, and, in many instances, unreliable.

Most infrastructures consist of networks and systems, which can be end-user/individual devices or shared facilities. One area for R&D would be the application of network and systems theory, especially integrating ICT, which might lead to valuable insights and ideas. In addition, not all good solutions need to be centralized or hierarchical, which underscores the need for bottom-up development.

[33] Radio Frequency Identification – very low cost and often passive sensors for identifying and tracking goods. These will likely become embedded into most commercial goods over the coming few years. Critics worry about privacy issues, but some uses for supply chain management appear less controversial.

Infrastructure projects often require both public and private resources

In terms of finance, infrastructure projects require large investments, and the debate on public vs. private needs to be transparent and more informed. Public projects often have a large private component, if not outright outsourcing, and private projects in turn are often beneficiaries of public policies and specialized funding, and are generally subject to public regulation. An additional financing challenge is the process by which solutions are chosen for public projects in most countries – tendering. While this provides the impression of transparency, it severely limits the introduction of ICT and other new technologies into infrastructure or other projects. No vendor or service provider unilaterally adds ICT if it is not in the requested "spec" since their solution is likely to be more expensive, regardless of the fact the use of ICT would provide additional benefits and even turn out to be less expensive.

ICT has the potential to positively impact infrastructure, but it does not function in a vacuum. Organizational, institutional, and structural issues can often impede the realizations possible from ICT, and without appropriate reforms or new implementation models ICT's value can be diminished. However, there are instances where ICT can sometimes help overcome institutional rigidities, e.g., by allowing outsourcing of specific tasks and diminishing the power of unions intransigent to change.

ICT can increase transparency, provide better information for decision-making and operations, and increase public pressure for reforms. Transparency alone doesn't always *speed* decision-making, as in many processes there are dislocations amongst stakeholders—some winners and some losers. To realize the full benefits of ICT requires the active participation of all stakeholders and this, in turn, needs human capacity building. In addition, all solutions should be adapted to local circumstances and needs. Externally imposed solutions have usually not been effective or sustainable.

Basic Human Needs and Development

Food and Agriculture

Overview

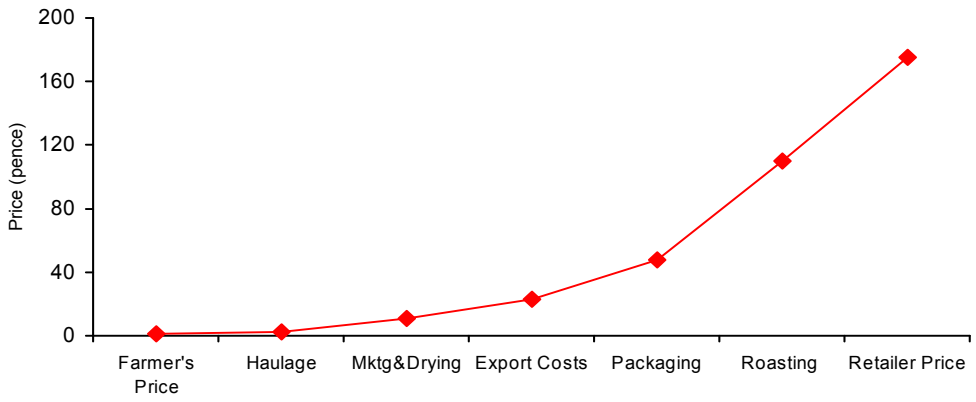
Food supplies have grown with population, but local and regional shortages remain a concern

Food is a basic human need, and agriculture (including fisheries, farming, livestock, etc.) employs the bulk of the global population. Technological improvements have kept pace with population growth, averting global shortages of food, but regional imbalances and lags remain, especially in Sub-Saharan Africa.

The MDG target of halving the number of undernourished by 2015 is difficult to realize at the current rate of reduction of hungry individuals (estimated at ~8 million a year on average). The task requires paying concurrent attention to increase in farm productivity, increased employment/livelihood opportunities in rural areas and improved conservation of natural resources. Greater investment in biotechnological research in relation to agriculture and trade is widely acknowledged to be a key factor in ensuring food security for all.[34] A number of professionals cite unbalanced global trade practices as a major impediment to improving the lives of farmers in developing countries; developed countries maintain their subsidies, tariffs, and interventions are necessary to maintain rural quality of life, if not lifestyles.

[34] Biotechnology doesn't necessarily mean genetically engineered crops; the green revolution involved biotechnology without genetic engineering.

Even within national borders, systems for price discovery and supply chain improvements can be vital for farmers, increasing their share of the retail price from the 5-25% they often receive for products (or lower, for the retail example of coffee, Figure 9).



Source: "Earth" Special, The Guardian (2002)

Figure 9: Value-chain for a Cup of Coffee (UK)

Agricultural output depends on both the land available as well as the productivity (yield). The availability of arable land has reached a plateau, and, combined with a rising population, leads to lower per capita land for grain production (Table 8). The only solution is increasing the output from the land—improving productivity.

Year	Arable land (10^6 ha)	Per capita arable land (ha)	Per capita grain harvested area (ha)
1700	265	0.44	n.a.
1850	537	0.44	n.a.
1920	913	0.45	n.a.
1950	1,170	0.47	0.23
1980	1,500	0.33	0.16
2000	1,450	0.23	0.12
2025	1,300*	0.16	?
2050	1,200*	0.13	?

Source: Rattan Lal (2003) Washington Workshop

* Different methodology; rounded estimate

Table 8: World Agricultural Land Availability

Agriculture needs to be sustainable – environmentally and economically

Soil cannot produce more than the inputs it takes in – else it will degrade and require ever greater inputs up to the point of unusability.[35] *Sustainability* is a fundamental part of long-term agriculture, which is based on:

- Preserving the natural resource base
- Maintaining the soil's productivity
- Maintaining environmental quality
- Alleviating human drudgery and suffering – making agriculture a viable and respected livelihood

[35] "Lal's Law of Marginality: Marginal soils cultivated with marginal inputs produce marginal yields and support marginal living."

The Green Revolution of the 1960s was realized by growing input-responsive varieties of grains on fertile soils significantly enhanced by fertilizers and irrigation. About 40% of the global food production comes from the 17% of farmland that is irrigated.[36] However, the growth of irrigation is slowing, and is now under 1% growth annually. In addition, nutrient input to the soil, which grew six-fold between 1960-1990 (25 million nutrient tons to 150 million tons), is only expected to grow by 50% in the subsequent three decades. The regional disparities highlight the importance of inputs. Fertilizer use in Tropical Africa is between 2-19 kg/ha, or only 2.5% of the world's consumption. Asia uses 73 kg/ha, which is lower than what the western nations consume. To compound matters, only 2% of irrigable land area in Africa is presently irrigated. Differences in inputs explain, in part, the enormous disparity in productivity (Table 9).

	World Cereal Yield (tons/ha)
World average yield	3.31
Highest yield (Belgium)	8.48
Lowest yield (Botswana)*	0.24

Source: FAOSTAT data (2004)

**Data for Cape Verde appear incomplete, showing 0.2000 tons/ha for the last two years, a dramatic decline over 5 years prior.*

Table 9: World Cereal Productivity

The answer is not merely increasing inputs to the soil. In fact, over-irrigation can lead to dramatic soil degradation such as water saturation, reduced aeration, salinity, runoff of nutrients, proliferation of weeds, etc. Soil degradation might be a physical process, but it is fueled by extended neglect and misuse of natural resources and not utilizing the scientific findings that could have saved the land from degradation.

Enough information and knowledge in agricultural sciences are now available to grow sufficient food with reasonable geographic and economic equity. Unfortunately, in many developing countries, technical know-how is not easily translated into practical strategies, especially not in the context of economic, social, cultural, political and ethnic realities. This is where ICT can play an important role, beginning with education, but extending to soil analysis, weather analysis, market analysis, etc. Looking at how different forms of farming affect land requirements per capita, technology and practices are the differentiating factor (Table 10).

[36] Data and information in this section draw extensively from Rattan Lal, Washington, D.C., Workshop Presentation (2003).

Farming System/input level	Ha/person
Shifting cultivation	2.65
Low traditional	1.20
Moderate traditional	0.60
Improved traditional	0.17
Moderate technological	0.11
High technological	0.08
Special technological	0.05

Source: Rattan Lal Washington Workshop Presentation (2003)

Table 10: Typical Land Requirements for Different Farming Systems. Increasing productivity in higher technology systems includes use of ICT.

Challenges

1) Increase the rate of reduction in the number of hungry individuals from the current rate of about 8 millions per annum to over 22 millions per annum
2) Improve food production for enhanced nutrition and health
3) Preserve natural resources including water
4) Prevent land erosion and stabilize land quality
5) Increase access to markets
6) Value addition through agro-products and food processing
7) Enhance and make available education about best practices solutions for improved output and incomes
8) Improve agricultural practices, including appropriate use of biotechnology
9) Increase livelihood options in rural areas, taking out a substantial fraction from a sole dependence on agriculture
10) Help to minimize suffering from catastrophic failures in agriculture, which causes human suffering as well as increases pressure for urbanization. Establish adequate safety nets (public and/or private) to protect the rural population affected by crop failures
11) Reduce wastage and spoilage of produce
12) Development of hygienic and non-perishable storage and packaging systems, while maintaining environmental compatibility

Barriers

1) Limited institutional accountability and capacity, and lack of dedicated effort and political will to end hunger anytime soon (through actions and funding)
2) Poor access to education in agricultural practices; limited ability to participate in exchange of knowledge between experts and farmers as well as farmer to farmer exchanges
3) Limited rural infrastructure for food processing and other value addition
4) Lack of appropriate technologies and organizational structures for monitoring water usage, contamination, drought prediction and other resource control mechanisms
5) Lack of access to regional/national and global markets for goods; limited price and other information on other regional/national markets for agricultural products. No consensus

on allowing gradual integration of global commodity trade and markets; simultaneous fragmentation of local markets

6) Existence of "perverse" subsidies that compensate (ecologically as well as economically) inefficient production practices
7) Actual or perceived corporate dominance and of advanced technologies, with monopolistic effects on farmers
8) Declining investment in application of frontier technologies in agricultural research and lack of investment in research on technologies for off-farm enterprises
9) Globalization unmindful of local concerns

Measures for Success and Failure

1) Increased nutritional levels across the population, with increased food production
2) Increased access to regional/national and global markets, with improved share of end-user price going to the farmer
3) Reduction in spoilage of food at the source and in transport
4) Development of systems for monitoring of land usage, water usage, drought prediction and other resource control mechanisms
5) Development and use of ICT for knowledge networks in agricultural practices
6) Ability to process food and provide value-addition
7) Viability of farming as profession, with a reduction in urbanization
8) Enhanced adoption of ecologically sound production practices on the small farm

Role of ICT

ICT can help with both the physical production of food, as well as improving agriculture as a livelihood.

- Sensors and Information Systems – to optimize inputs based on soil, water, crop, and environmental conditions
- Interaction with specialists – two way audio-visual communications for pest management, e.g., diagnosis of diseases through digital images and expert advice
- Marketing and logistics enhancement – price discovery, bargaining power, and supply chain efficiency

Examples of Needed Research

1) Drip and advanced irrigation systems – this will impact sustainability and reduce water needs
2) Solutions to match inputs and effort (fertilizer, pesticides, sowing timing, etc.) with soil, crop, weather and other conditions, which can also be linked to advanced irrigation systems
3) Determine role and potential for ICT vis-à-vis physical inputs required for productivity
4) Making agriculture related information available and compatible with available hardware and communications technologies (e.g., cell-phones – as a hardware platform and communications means)

One major issue with increased use of ICT (common to many aspects of development) is the asymmetric ability of stakeholders to benefit from ICT. Large buyers or traders of commodities are more likely to be able to squeeze farmers for lower prices than farmers are

able to bargain for better prices. This was seen in the case of coffee, where retail prices stayed flat or grew, while the prices paid to farmers declined. One suggestion has been to develop ICT based auctions, which can mitigate the market power of large buyers. However, auctions should be distance enabled, as ITC's e-*Choupal* system shows.

e-*Choupal*: ICT for rural agriculture[37]

e-*Choupal*[38] is the successful initiative developed by ITC Ltd., a major Indian conglomerate with an agribusiness arm. Within four years, ITC has established roughly 5,050 e-*Choupal* kiosks covering 31,000 villages and 3.1 million farmers. This allows the farmer a choice to sell directly to ITC or the traditional market (*mandi*) for produce. The first use was for soybean, but it is now extended to other foods. ITC pays for installing the system, which is operated by a local village farmer, the *Sanchalak.* (who is literate, respected in the community, but typically not e-literate).

The traditional *mandi* system, which was inefficient, produced high profits for the middleman, but farmers had to travel with their output to sell their crop. While there were auctions in place, the sunk cost of travel meant farmers typically took what they could get. Now, farmers are empowered within the village with free information on pricing, independent of any transaction they may choose. In addition, the system provides real-time and other information such as weather, best practices, etc., and provides e-commerce transactions with better pricing and quality for seeds, fertilizer, etc., as well as other goods and services that have been quality-controlled.

This has been successful because ITC brings a ready market and transformed supply chain system for farmers. In addition, they have the farmer's trust, and the *Sanchalak* takes a public oath to serve the villagers. *Sanchalaks* provide the housing for the equipment and the operating costs of ~$100/year (power, telecom usage, etc.—the latter is decreasing with deployment of VSAT systems by ITC), and gain prestige, a working computer, and a commission from ITC on all completed transactions (but browsing and the information is free for farmers).

The e-*Choupals* have been established within walking or cycling distance for a farmer (one per cluster of 5-6 villages), and the multipurpose warehouses/processing centers (where the grain is delivered) are within tractor driving distance. The 2003 transactions, without spanning many crops, were $100 million and over the next decade, ITC aims to extend this system to 100,000 villages (20,000 installations), or 10 million farmers, and transactions of over $2.5B. The system works because the farmers find upto 20% higher prices for their grain, and also reduced costs overall, and ITC has reduced their transaction costs by 75% (Table 11). ITC also increases its quality control and can offer traceability to its customer base, important due to the small farm sizes in India.

[37] This section draws from: Digital Dividends Case Study, "What Works: ITC'S e-*Choupal* and Profitable Rural Transformation," Kuttayan Annamalai and Sachin Rao, August 2003; "Going Direct to the Farmer: ITC's e-*Choupal* Initiative," Ravi Anupindi, presented at SCTL Roundtable July 2004; information from ITC through personal discussions.

[38] Hindi term for a rural meeting place; it is different from a *mandi*, or market-yard.

Mandi Chain				e-*Choupal* Chain			
Farmer's Costs		**Processor's Costs**		**Farmer's Costs**		**Processor's Costs**	
Trolley Freight to *Mandi*	100	Commission to Agent	100	~~Trolley Freight to *Mandi*~~	~~100~~	Commission to ~~Agent~~ *Sanchalak*	~~100~~ 50
Labor – Filling & Weighing	70	Cost of Gunny Bags (net)	75	~~Filling & Weighing Labour~~	~~70~~	~~Cost of Gunny Bags (net)~~	~~75~~
Labor – *Khadi Karai* (holding)	50	Labor – Stitching, Loading	35	~~Labor – *Khadi Karai* (holding)~~	~~50~~	~~Labor – Stitching, Loading~~	~~35~~
Handling Loss	50	Labor at Factory (Unload)	35	~~Handling Loss~~	~~50~~	Labor at Factory (Unload)	35
		Freight to Factory	250			Freight to Factory	~~250~~ 100
		Transit Losses	10			~~Transit Losses~~	~~10~~
Totals	**270**		**505**		**0**		**185**

Source: *ITC (2005)*

Table 11: Costs for Mandi vs. e-Choupal (Rs../ton, e.g., soybeans)

Some lessons from the system are:

- A local stakeholder is vital to ensuring trust and alignment of incentives – the *Sanchalak.*
- Competition and choices for the farmer are key (for e-commerce/suppliers/trade fulfillment) – ensuring efficiency and that farmers benefit.
- The system must be tailored to the crop at hand and its specific supply chain needs.
- Telecommunications are a large fraction of the cost, both operating and capital; one needs to innovate to find less expensive last-mile connectivity solutions.

(Rs.)	Printer	Power Related	VSAT	PC	Total
2003-04 Costs	7,000	15,000	70,000	30,000	122,000

Source: Digital Dividends: "What Works: ITC'S e-Choupal and Profitable Rural Transformation" (2003)

Table 12: ITC's e-Choupal Capital Costs per Kiosk (2003-04)
[One US$ ~ 45 Rupees]

- e-Literacy is not an issue – a local person can learn this (any) technology as long as he/she has a stake in it and benefits from it. In fact, *Sanchalaks* learned to transliterate Hindi using an English keyboard as the most efficient manner of communicating (Hindi script can be cumbersome, requiring multiple keystrokes per character).
- There are synergies for this infrastructure (for agriculture and for general education, retailing, e-commerce, e-governance, etc.) ITC is extending e-health and e-education into rural areas through this platform, and partnering with NGOs for micro-credit facilities, soil and water conservation, etc.
- There are certainly some "losers" – e.g., the *mandi* middlemen; ITC still pays *mandi* taxes to the government, but there may be other regulatory concerns with growth.

Healthcare

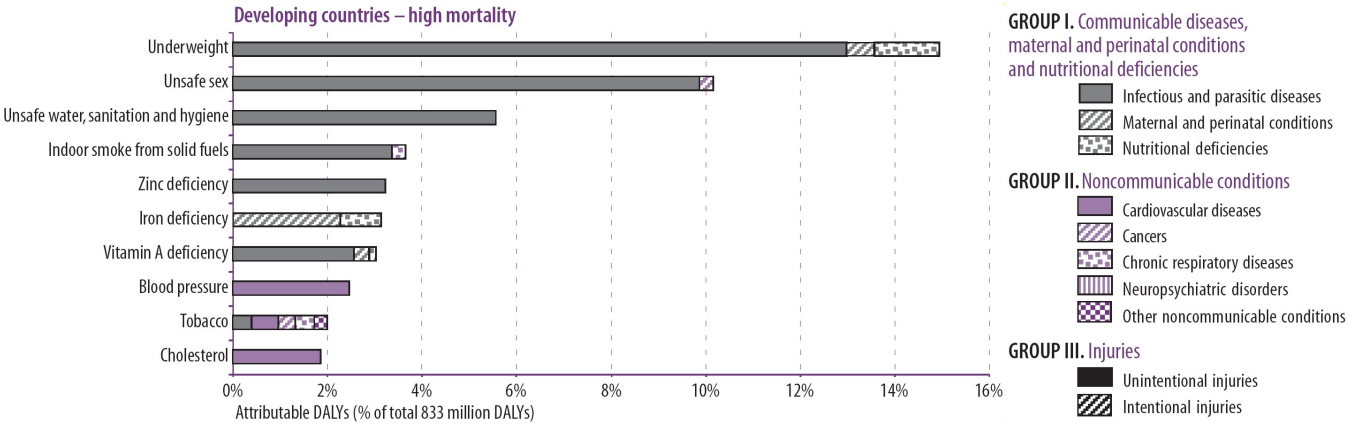
Overview

Three major diseases now take a heavy toll of lives in developing countries, especially in Africa: HIV/AIDS, tuberculosis (TB), and malaria. These add up to almost 6.5 million deaths a year with AIDS deaths totaling almost 3 million (2.3 million in Africa alone) closely followed by TB with 2 million deaths (1.5 million in Africa) and malaria with 1.5 million (960,000 in Africa). Deaths from two of these are largely preventable today with appropriate drugs and precautions, and the ravages caused by AIDS can at least be minimized. Infant mortality deaths, largely due to water-borne diseases, malnutrition, and lack of post-natal care, have also reduced the life expectancy in many developing countries. Diarrhea alone kills an estimated 2.2 million people annually, mostly children. Indoor air pollution has become a major killer in developing countries (while urban air pollution has reduced in middle and high income countries). Other major diseases in developing countries, especially from a growth rate perspective, are cardiovascular, diabetes, and hepatitis, deaths from which are preventable to varying degrees.

There is a well-established inverse relationship between overall development and burden of disease. However, even for a given level of income (a proxy for development), indicators such as malnutrition vary significantly amongst countries. This suggests that there is more to health than mere economic wellbeing.

Successful healthcare, like other areas of development, requires improvements outside the domain, such as in energy, water and sanitation, etc.

Globally, healthcare is an enormous sector of the economy, roughly double that of agriculture in size (and relatively much larger in developed countries). Most modern systems of healthcare focus on government policies and formal healthcare provision. However, if we examine the causes of disease in developing countries, and their associated reduction in life-years, we can immediately recognize the need for increased expenditure on determinants outside the modern health system, especially the household and community (Figure 10).[39]



Source: World Health Report 2002: Reducing Risks, Promoting Healthy Life, WHO

Note : DALY – disability-adjusted life year

Figure 10: Burden of Disease Attributable to 10 Selected Leading Risk Factors in High Mortality Developing Countries

[39] Portions of this section draw from Washington, D.C., Workshop presentation by W. Henry Mosley, 2003.

Most factors that lead to disease in developing countries lie outside the modern healthcare system. Even their diagnosis is not integral to many systems, and aggressive prevention is not systematized (the notable exception being vaccination). If we study some of the causes in greater detail, we clearly see the *household* is the primary agent for promoting health (Table 13).

Undernutrition	Food production/purchase and storage; Dietary selection and meal preparation; Family food allocation; Dietary practices in pregnancy and postpartum; Breastfeeding and complementary feeding practices; *etc.*
Unsafe sex	Negotiating gender roles and sexual relationships; "Protecting" unmarried daughters (and sons), delaying sexual debut, arranging marriages, secluding women, limiting sexual partners, utilizing condoms; *etc.*
Unsafe water, sanitation and hygiene	Collection, storage, utilization of water; Bathing, washing clothing, bedding, utensils, use of soap; Food preparation (incl. Infant formula) and storage; Latrine practices and waste disposal; *etc.*
Indoor smoke from solid fuel	Use of biomass for fuel; Use of (inefficient) open indoor fires; Lack of windows/ventilation, *etc.*

Source: W. Henry Mosley, Washington Workshop Presentation (2003)

Table 13: Household Activities and Burden of Disease

Given the prominence of the household in determining health, the female is the de-facto healthcare provider for most rural underserved communities. She is not only involved or responsible for the above activities, but is also the first line of defense, providing triage and rudimentary care. One requirement would thus be to empower her with information both medical as well as relating to common household activities and how these impact health. This also relates to overall gender empowerment and related social issues.

A number of developing countries, especially in Latin America, have found visible success in utilizing social networks to improve healthcare. In some countries, trained healthcare workers are assigned to small groups of families, visiting them regularly to provide pre-natal and other basic care. This has had a significant impact in reducing maternal and early childhood mortality.

Ultimately, as with many aspects of development, outside factors not within the domain determine the overall level of development; in healthcare there are inherent linkages to infrastructure such as water/sanitation and to agriculture. Nutritionists now point out that merely growing enough food (calories) is not the only challenge. Carbohydrates have grown dramatically in supply and so many of the global poor, though not suffering from starvation, lack adequate proteins (including dairy), vitamins, micronutrients, etc. for improved health and productive capability.

Challenges

1) Increase longevity and survival statistics
2) Reach the entire population and educate them in a persuasive manner on health issues

3) Ensure that malaria and TB are eradicated and the affected cured
4) Make educational information universally available on how to prevent the spread of AIDS and help the victims from being ostracized
5) Provide health care and health information to people in difficult-to-reach rural areas, including through outreach programs
6) Make telemedicine systems routinely available in all remote areas
7) Minimize deaths from water-borne diseases and poor sanitation
8) Provide education on pre-natal and post-natal care
9) Improve healthy lifestyles (diet, exercise, etc.)
10) Incorporate traditional and so-called alternative medicine in a scientific manner.

Barriers

1) Lack of available and affordable healthcare
2) Poor governmental investments for healthcare
3) Acute scarcity of hospitals and healthcare facilities, and overcrowding in existing ones
4) Scarcity of lifesaving drugs and equipment, and their high cost
5) Poor water sanitation and hygiene, and limited availability of infrastructure such as electricity, telecommunications etc.
6) Lack of information on healthcare options, hygiene, and personal health
7) Lack of clean fuels for cooking and limited enforcement of urban air quality standards
8) Shortage of well-trained health professionals, especially in rural and economically depressed areas
9) Spurious medicines and quacks
10) Modern lifestyles with increased stress and pollution, unhealthy diets, and reduced exercise
11) Increasing tobacco consumption, especially in developing countries
12) Ostracizing people with infectious diseases
13) Gender discrimination and disparities due to income
14) Increased resistance to drugs by pathogens due to indiscriminate usage
15) Lack of insurance options or safety nets
16) Lack of incentives for health care practitioners to move to rural areas
17) Lack of well-defined measures or data on quality of life, especially for the elderly
18) A system that emphasizes cures over prevention, and also sets research priorities based on “market,” effectively shutting out developing country diseases

Measures for Success and Failure

1) Increases in life expectancy
2) Reduction in infant mortality and maternal deaths
3) Millennium goals for reducing the spread of TB, Malaria and AIDS
4) Immunization of all children under 5
5) Gender equality in healthcare
6) Sustainability in percentage of GDP devoted to healthcare

Role of ICT

ICT can play an important role in healthcare around the world, both in developing and developed countries. Healthcare can be 10+% of the GDP in some countries, and simply using ICT for streamlining logistics and operations alone can lead to significant returns. Telemedicine can extend the availability of medical specialists to rural and other underserved areas. ICT can also play a role in societal health issues, including diseases that are communicable or that affect a segment of the population (especially epidemics). Some funding and efforts might be directed towards epidemiological detection of malicious biological incidents (bio-terrorism), but the general principles and systems can apply. One of the primary roles ICT can play in developing regions is on education: An ounce of prevention is worth a pound of cure.[40]

Questions for stakeholders who aim to integrate ICT into modern healthcare systems include:[41]

- Is there a functioning information system that would *gain in performance* with new ICT?
- Are there growing operational needs, e.g. logistics, finance, personnel, services, that ICT systems could *more easily manage*?
- Are there new data gathering and analytical needs that ICT systems could *simplify*?
- Are there knowledge and skill building needs that can be *efficiently facilitated* by ICT?
- Are there global and local interaction needs that would be *best met* by ICT systems?

ICT's impact has been easier to find within modern healthcare systems, which is often beyond the reach of a large fraction of the population

There are many successful examples of ICT for healthcare projects, such as the use of hydrologic sensors, satellite imagery, and forecasting software to help eradicate the black fly—which causes river blindness—across parts of West Africa. Optimized insecticide spraying protects 30,000,000 people, and frees up 100,000 square miles of land. However, most cases are niche and ICT has yet to become integrated into societal healthcare, especially not to the extent the technologies could allow. Some gaps include: [42]

- Lack of stakeholder participation, especially those that are directly afflicted
- Poor integration of local information and locally relevant information
- Overemphasis on top-down decision-making and management
- Limited integration of ICT into existing programs
- Limited integration of various high and low-tech solutions, such as mobile phones, TV, radio, etc.
- Insufficient thought given to barriers to ICT use (outside the healthcare domain)
- Insufficient attention paid to the role of intermediaries in ICT for healthcare

---

[40] ICT need not be computers and the Internet. In the case of HIV/AIDS, the most common source of information for laypeople, by far, was radio *(HIV/AIDS and Behavior Report*, June 2002, United Nations).

[41] Presented by W. Henry Mosley at the Washington Workshop.

[42] Adapted from *The Digital Pulse: The Current and Future Applications of Information and Communication Technologies for Developmental Health Priorities*; Chapter 1: State of Health ICT4D: Issues and Gaps by Communication Initiative (January 5, 2004).

Examples of Needed Research

ICT is already being integrated into modern healthcare systems, but ICT needs to be appropriately scaled for the provider at hand (who might be an semi-literate midwife).

1) Making healthcare information available and compatible with available hardware and communications technologies (e.g., cell-phones – as a hardware platform and communications means)
2) ICT solutions that are user-centric and user driven, and don't require ICT specialists to operate or maintain

Education

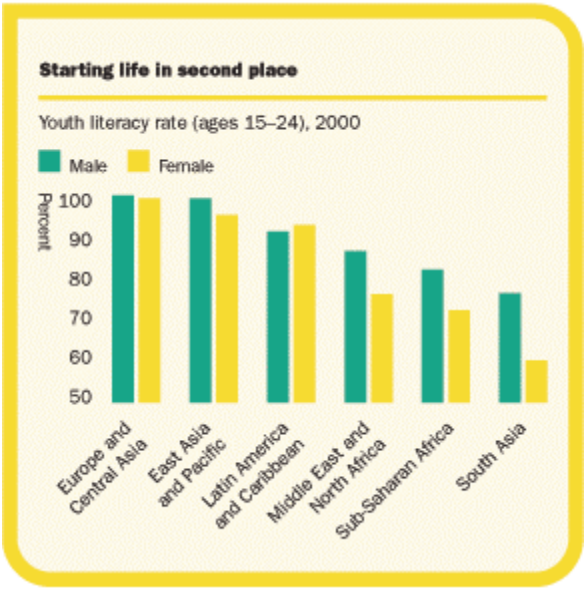
Overview

ICT can enhance education at all levels, but there is also a need for improved education for developing and improving ICT skills

Education has two components, basic education (literacy) and advanced (which may or may not include specialized or ICT training). Education highlights a number of divides, including gender (Figure 11). Much of the deliberations at the Bangalore Workshop were on basic education and eradicating illiteracy.

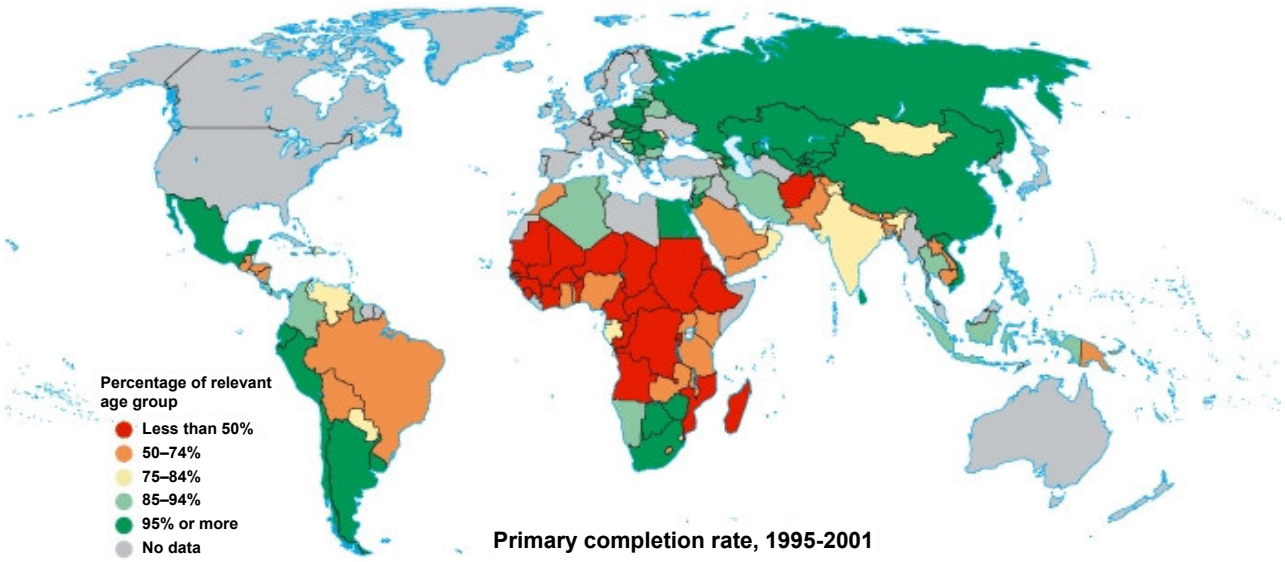
At present, over 120 million children are not in school. Many governments have statutes for universal basic education, but limitations of infrastructure prevent them from fulfilling this mission. In addition, families themselves face (and impose) constraints on sending children to school, especially girls (who are put to household and outside work). Efforts towards complementary development may have a strong "free rider" benefit in increasing school enrollments. In the Indian state of Himachal Pradesh, almost 100% of appropriate age children are in primary school. This was achieved not just by an increased budget for education but also by the government improving availability of piped water into villages and small sized bottled gas cylinders for cooking. This freed the children up from having to fetch water or cut down firewood for cooking. In the Indian state of Tamil Nadu, a midday meal scheme at schools drew in the large majority of children, and has even led to virtually zero population growth rate.[43]

[43] Demographers expected declines in fertility after a generation, as girls would go to school, become empowered, marry later in life, etc. To their pleasant surprise, families began having less children very soon, as the girls—who went to school in part for the meals—were no longer available as baby-sitters for the mothers, who have to work in the field.



Source : UNESCO and World Bank staff estimates

Figure 11a (above) and Figure 11b (below): Gender Education and Primary School Completion Inequalities. MDG 3 is to eliminate gender disparity in primary and secondary education, preferably by 2005, and to all levels of education no later than 2015.



Primary completion rate, 1995-2001

Source: Millennium Development Goals Website

Note: Western Europe, Australia, US and Canada all have nearly universal primary completion rates, making the map appear much more "green."

Challenges

1) Universal literacy, including adult literacy
2) Increasing female education levels to parity, beyond just literacy concerns

3) Establishing vocational and technical education programs, with curriculum relevance for employability
4) Make contents rich, affordable and available at all levels of learning, including a Universal Digital Library
5) Make contents available in different languages
6) Develop computer simulated experiments in sciences for students to perform and learn
7) Develop and disseminate programs to help children with learning difficulties or physical disabilities
8) Assist and empower teachers and provide them with tools for providing quality education
9) Modernize curricula to be relevant and worthwhile for students
10) Establish standards and certification procedures for education

Barriers

1) Lack of adequate governmental budgetary provision for education and training
2) Lack of governmental support and encouragement for learning; no mandate for universal literacy supported through action and funding
3) Limited checks on student achievement or capability levels; poor enforcement of standards
4) Curricula that are outdated and provide limited value to students; inertia or vested interests preventing change
5) Lack of qualified and motivated teachers; few incentives for choosing teaching as a profession
6) Overworked and underpaid teachers who have no incentives, resources or time to devote to learning and then using ICT
7) Competing claims from families to withdraw children from school (e.g., working in the fields)
8) Mistaken belief that ICT can “fix” education on its own, leading to misallocation of resources

Measures for Success and Failure

1) Universal literacy, especially with meaningful measures (“functional literacy”)
2) Increasing employment for women
3) Well-trained workforce with hands-on (learning-by-doing) experience
4) Increase in teachers and funding for education
5) Ability for anyone to access any educational content at very little or no cost
6) Reflection of increased education through overall economic growth
7) Increased patenting and innovation from developing countries

Role of ICT

ICT can help education and literacy, as it has the technological prowess of extensive reach, and provides options to tailor the output to meet individual needs at anytime of his or her choosing. More than such conveniences, ICT can overcome some of the major handicaps inherent in conventional education. For instance, it can provide quality education with appropriate graphics and experimental presentations that are today available only in a few select urban schools; it doesn’t discriminate on the basis of

gender or income, and can be made available in any language. These characteristics of ICT enabled education are available at any level including for courses in practical training, adult education or continuing education. Government programs are often required to bring ICT to under-funded schools. Chile's educational reforms of the 1990s included integrating ICT, and the *Enlaces* program of providing computers, connectivity, and software now reaches over 90% of students in government-assisted schools.[44]

ICT should enhance or supplement traditional education, not replace it

ICT can be used to enhance education and supplement traditional education. ICT for education need not be real-time interactive or online; television, radio, and post have all played a major role in education in countries ranging from Australia to China (where 44% of higher education students in the 1980s were using radio or TV based distance education (in combination with post)[45].

Workshop Participants were unanimous that while ICT can enhance education, it isn't a quick-fix for the institutional shortcomings of many current educational systems. These include the obvious issues such as under-funding, lack of teachers, etc., but also deeper issues such as lack of specialized or customized education for underrepresented segments of society. Given resource constraints, it is important for educators and planners to coordinate efforts and learn from what works and what doesn't, both within and across borders.

ICT should not become an additional burden for teachers

One of the main issues relates to capacity building for educators. ICT should not become another burden, in fact, another divide, upon teachers. They need hardware, software, training, and connectivity. One special potential for ICT is to allow easier customization and specialization of content, especially geared towards special classes of underserved or disadvantaged users (gender, age, disabilities, etc.) In addition, ICT can help reach those outside formal school systems, such as through TV, radio, and videos. One challenge is incorporating such non-traditional delivery mechanisms into funded and certified educational programs.

While education, especially primary education, remains the responsibility of the state, there is significant evidence that people not only want better education than that often available in public institutions, they are willing to pay the private sector for such services. This raises not only equity and class issues, but issues of quality and standards. Governments should regulate or monitor such private providers, but, at the same time, support them when they play a complementary role. The NGO developers of *Tarahaat*, the pioneering rural consumer online portal and solution, found education to be one of their most demanded and viable offerings. This provides evidence that rural consumers are capable of benefiting from ICT enabled education and services.

Examples of Needed Research

1) National and international coordination on education, perhaps through an International Liaison Committee
2) Solutions for easy scalability of ICT, especially teaching the teachers
3) Development of appropriate content, with access and availability (this includes digital libraries)
4) Efficient feedback systems that make expert teachers and advanced learning available to all students

---

[44] ICT and MDGs: World Bank Group Perspective, December 2003.

[45] ICT and MDGs: World Bank Group Perspective, December 2003.

e-Books and Digital Libraries

Carnegie Mellon, working with partners such as the Indian Institute of Science, is working on a Universal Digital Library project. The aim is to have online, with free access, one million books by 2005-06, and by 2020, have a large fraction of the world's books online. The global libraries have roughly 70 million unique books between them, in all languages (excluding journals and magazines), and the cost to digitize them is modest, ~$25/book—this is the cost to not simply digitize them as a picture but convert them to searchable text, that too in local languages.[46] The biggest bottleneck remains copyright, which is why the initial thrust has been on classics and other books out of copyright.

Most publications or media are not profitable (but a few are blockbusters), and many publications are out of print but still in copyright. One proposed model is for society to appreciate creative works and compensate authors in return for permitting open public access to their works. Libraries serve this function, but only a few countries like the UK have a compensation scheme to pay royalties to authors for lost revenues from free access to their books in libraries. If a government-funded payment scheme were to become universally accepted, we can create a global digital library that contains all out-of-copyright and out-of-print and out-of-money books, music and movies. This would lead to a win-win situation – the public would have access to works that would otherwise be inaccessible, and the author would have the pleasure of (and money from) knowing that his or her work is of value and relevance to society. A parallel model,[47] not mutually exclusive to public access models, would be for online digital publications to be an additional stage of publishing. Just like hardcover books are the most expensive (and released first), followed by paperback and then versions exclusively for sale in developing countries, "digitalback" versions could be offered at even lower prices, but after an appropriate delay of 6-18 months to prevent conflict with traditional sales.

Public funding of access to information is not a new idea. 100 years ago there were few public libraries. Until Andrew Carnegie made it a worldwide mission, a library as a "public good" was not widely acknowledged or acted upon. Today, it is estimated that global public spending on libraries is in excess of 40 billion dollars and that the US alone spends over 12 billion dollars annually in support of libraries. In the 21st century, since much of the information is likely to be digital and accessed via the Internet, it seems appropriate that an amount equivalent to the annual library expenditures should be set aside from public funds (perhaps gradually reaching parity over 25 years) to enable digital access to information and knowledge. But unlike physical libraries, where much of the costs are for buildings and people, in a digital library a significant portion of the funds (say 25%) could be set aside as royalty payments to authors and artists of creative works to be paid based on number of accesses rather than number of copies. The savings from not requiring as much physical space or maintenance might alone justify such a transition.

Basic Human Needs and Development – General Observations

In their daily lives, people recognize the need for information. Today, they mainly seek information as facts (prices, weather, etc.). From data we can extract information, and this can be analyzed and synthesized and, ultimately, we can achieve knowledge. Humans today perform these tasks using various modes of communication. In future some of these tasks can be done by machines, or at least humans aided by expert systems.

To foster such collaboration (and archive knowledge for future use) requires appropriately designed ICT that is available, accessible, and affordable. Across all the

[46] While there are several other large projects on digital libraries, CMU has a special focus on international languages and content.

[47] *Sustainable ICT for Emerging Economies: Mythology and Reality of the Digital Divide Problem – A Discussion Note (*2004). Raj Reddy, V. S. Arunachalam, Rahul Tongia, Eswaran Subrahmanian, and N. Balakrishnan.

domains for human development, appropriate content (dubbed “Content customization for cultural context” at the Workshops) requires innovations in ICT to make contents more inclusive for local stakeholders. Given infrastructural constraints, this might require solutions such as local caching and distributed storage. Even with governmental support, these activities would require new business models and creative financing to help sustain them. In addition to traditional participants (government, business, individual end-users, and philanthropists), collective ownership models (co-ops) or community systems were suggested as attractive models. These can also help empower women if they are targeted as stakeholders, a model used by the Grameen Bank and Grameen Phone in Bangladesh. Microfinance and affordable credit have been recognized as vital to helping ICT penetrate into underserved areas.

The Human Development Working Group proposed several activities over varying timeframes (Table 14).

Timeframe	*Activities*
2 Years	• Initiate several projects on customization
	• Foster courses targeted at ICT facilitators, etc.
	• Educate technologists about actual potential users and their behaviors
	• Educate potential users about the possibilities
	• Start to build the database of recent successful and failed case studies
	• Sensitize policymakers to issues
	• Initiate several projects on customization
5 Years	• Reports on existing deployments
	• Have graduated several advanced degrees in ICT for SD
	• Have established forum(s) where these issues are dealt with
	• Replication to other developing region(s)
	• Influence worldwide designs/processes
10 Years	• Products originate from developing (now developed?) communities
	• Customized content ubiquitous
	• Access to remote (geo and socially) regions
	• Government/private partnerships facilitate equity
	• Government seeds new ICT initiatives

Table 14: Action Plan and Activities – ICT for Human Development – Bangalore Workshop Working Group Recommendations

Economic Growth and Employment

Overview

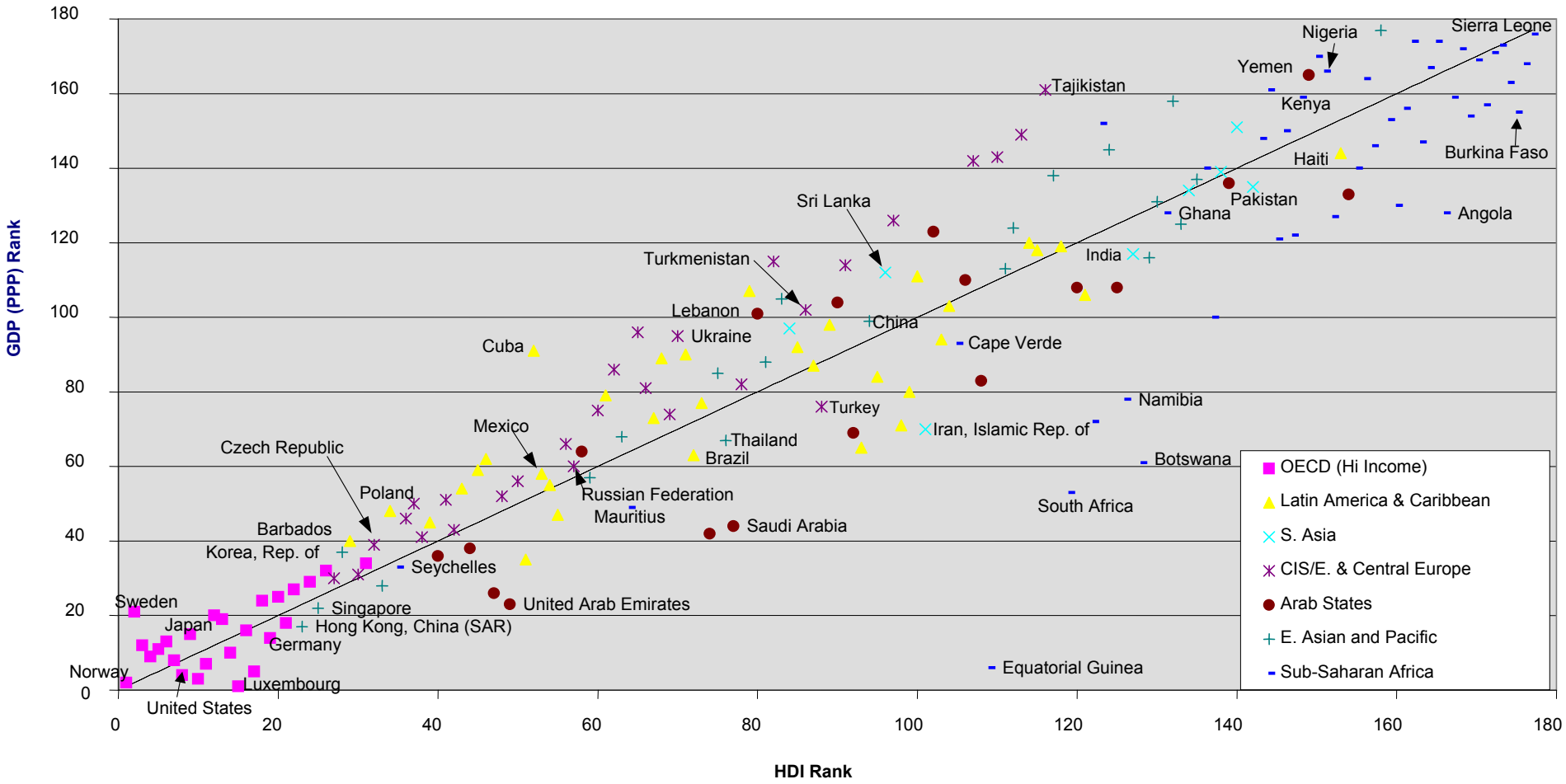
Economic growth is recognized as one of the key factors to improved quality of life, though the Human Development Index (HDI) doesn’t perfectly correlate with GDP (Figure 12). The differences become starker when we compare the variance within a region, but regions as a whole tend to follow the trend.

Distribution of wealth, captured by the Gini Coefficient,[48] provides one view of inequality, but such data as published rarely incorporate sub-regional granularity, or breakdowns paralleling other divides (gender, age, community, rural/urban, etc.)

While HDI has become an accepted metric for development, much of the attention of policy-makers focuses on economic measures, such as GDP. In addition to concerns over data accuracy and granularity, such measures fail to capture much of the activity in many developing regions, which occurs in the informal sector. One of the key challenges is to ensure that economic growth is inclusive and broad-based.[49]

[48] Gini Coefficient – a metric of income inequality based on the distribution of income by households or individuals. Its computation is based on shape of the Lorenz Curve, which plots the cumulative income by individual or household, from 0 to 100% of the population.

[49] One school of thought, captured in Kuznet's Curve, is that "development" (economic growth) will initially worsen income inequality, taking many years to stabilize and trickle down.



*GDP data is for 2002, PPP
Created from UNDP Human Development Report 2004 Data

**Country groupings are per Human Development Report 2004, except Turkey and Cyprus, which are bundled into CIS/E. & Central Europe

Figure 12: Difference Between HDI Rank and GDP (PPP) Rank. These are rankings only and cannot be compared between GDP and HDI. Higher numbers indicate poorer performance.

There are numerous studies that show the *correlation* between economic development and ICT or networking penetration. However, these do not necessarily show *causality*. If a group cannot pay for certain ICT, the facilities either require continuous subsidy, or fall into disuse. Data from the Sustainable Access for Rural India (SARI) project in Tamil Nadu, India, showed that with a 1% increase in earning, people increased ICT usage by 1.4%. It is unclear how much the increased ICT usage led to increase in incomes. Many reports or figures are only anecdotal or case specific, e.g., using ICT for crop price discovery.

ICT and economic development can be categorized into two categories:
[1] servicing and development of ICT technologies and industries such as call centers, back office services, hardware, software and process development, and [2] using ICT enabled processes and services to enhance efficiency, create more opportunities and generate new avenues for employment.

In terms of ICT Services (Type [1]), there is a backlash from developed countries against such offshoring—indeed it was an issue in the 2004 US presidential elections. In his Keynote Address, Joseph Stiglitz argued this fear is overblown, despite the vast labor pool in developing countries. One reason is the number of developed country jobs (especially ICT enabled or based) that are "contestable" today is a fraction of a percent of the employment needs. From a developing country perspective, this is a yet smaller percentage of the workforce that can find such employment. While India, Philippines, and even Ghana have had some success in ICT services for global (Western) needs, developing countries must expand their domestic markets to make ICT growth driven by local needs and opportunities, as Brazil has done.

The services sector is almost $^2/_3$ of the world economy, and is increasingly dependent on ICT

Even though the fraction of the population servicing the West through ICT may be small, the trickle-down and spin-off effects are significant. The developing country ICT professionals (typically young), whether they work in their native countries or abroad, interact closely with the West, absorbing part of its culture and some of the business practices as well. They, in turn, demand better quality services – from their governments and their private sectors. While the brain drain still continues to be relevant, there is a perceptible change with professionals from China and India returning to their own countries.[50] It remains to be seen whether the reverse brain drain grows not only in China and India but in other countries as well. This would depend critically on available opportunities, modernization of the infrastructure and business practices in developing countries.

An immediate and ultimately greater benefit from ICT may be in traditional industries, in increasing efficiency and competitiveness. Globalization, recent hiccups aside, is not slowing down, and developing countries can use ICT to become globally competitive, instead of becoming only importers of products. In addition to logistics and supply chain improvements, ICT can enhance transparency; corruption is cited as a major barrier to increased economic trade and output.

While the late 1990s saw increased hype over Business to Consumer (B2C) e-commerce, Business to Business (B2B) is roughly 95% of e-commerce.[51] While the split is not known for developing countries, given the lower penetration of computers with consumers, it is likely that businesses, government, and services (schools, hospitals, etc.) would be the major users of both computers as well as computer based transactions. In spite of this lack

[50] China has had the most success in bringing back its professionals after periods abroad—spanning most segments of the economy, not just ICT—with hundreds of thousands returning.

[51] E-commerce and Development Report 2003, UNCTAD (2003)

of local demand, businesses in developing countries are learning to use e-commerce for trading in developed country markets. While larger orders are now being executed through electronic exchanges or portals, some products (such as handicrafts) are being sold in the West through online marketplaces or auction services (equivalent to Ebay).

In many developed countries, the private sector, especially small and medium enterprises, are the engine for economic and employment growth. In contrast, most developing countries continue to have state-centered economies, with Government directly providing many services that in the West are often in the hands of private, but regulated, companies. While there is increased pressure for privatization and reforms, externally enforced reforms have rarely produced expected outcomes. At the Bangalore Workshop, Joseph Stiglitz summarized the lessons of East Asian and other rapidly developing economies where the role of government is at its best as an enabler, focusing on services such as infrastructure and education.

Almost all developing countries have created national Poverty Reduction Strategies under consultation with the World Bank. These documents have become the primary instrument for financing development by such agencies, increasingly to the governments directly instead of to the individual projects. Virtually no Poverty Reduction Strategy Paper by any country mentions the use of ICT in development or poverty reduction. Some development professionals feel this imposes limitations on financing ICT based or enhanced development or poverty reduction projects, at least until there is explicit discussion and introduction of such wording into these documents.[52]

Economic Growth and Poverty Reduction through Servicing ICT Industries [1]

Challenges

1) Develop human resources with appropriate skill sets for technology needs
2) Targeted training to use ICT to meet different cultural and social needs
3) Create appropriate organizational structures and business processes to benefit from ICT created opportunities
4) Develop appropriate governmental policies for transparent commercial practices and for creating fiscal incentives to enhance ICT opportunities

Barriers

1) Poor literacy levels, lack of opportunities and environment for universal secondary and affordable tertiary education in many regions of developing countries; poor quality of education and training, even which is unaffordable to a large population; lack of opportunities for continuing education and life-long training
2) Lack of institutions to train people for addressing local/regional needs, coupled with neglect of local needs by industry
3) Brain drain of talented people to urban areas and developed countries
4) Absence of business intelligence units to inform of opportunities and provide linkages
5) Lack of tradition/experience in running businesses that interact globally
6) Lack of governmental experience in nurturing ICT industries with appropriate fiscal incentives
7) Concerns in developed countries over loss of jobs to developing countries (outsourcing)

[52] UN ICT Task Force Global Forum deliberations, Dublin, Ireland, April 13-14, 2005.

Measures for Success and Failure

1) Increase in the share and growth of ICT and related services in the economy
2) Creation of governmental programs and incentives for ICT education and other relevant areas for ICT enabled growth such as e-commerce
3) Increased use of appropriate standards for ICT enabled services
4) Establishing a number of training as well as collaborative programs in ICT both within the country and abroad (developing and developed countries)
5) Bottom-up demand for ICT based services for local and domestic needs

ICT Enabled or Enhanced Employment Generation and Poverty Reduction [2]

Challenges

1) Identify areas to utilize if not substitute IC technologies in business and government processes to improve the reach, volume and quality of services, and minimize transactions costs. This especially applies to agriculture, which employs the largest fraction of the world's population
2) Develop new opportunities for meeting local needs
3) Identify new avenues for ICT that substitute mass production by catering to individually customized needs (mass customization)
4) Develop new business models and processes to harness the opportunities in the global market place
5) Identify opportunities that substitute labor-intensive production by computer controlled/technology based processes, taking note of the local genius of the people. This extends to reduced use of natural resources
6) Provide appropriate financial services and tax incentives to promote entrepreneurs focused on the local/regional/domestic economy
7) Eliminate gender and other disparities in training, employment, and opportunities
8) Improve transparency in economic transactions and culture of awareness for the need for transparency

Barriers

1) Ignorance of new ICT opportunities in various areas of the economy
2) Scarcity of people trained in ICT and business opportunities
3) Lack of affordable and adequate infrastructure; poor planning for its growth
4) Governmental lethargy to change existing structures and rules of business to quickly respond to innovators needs
5) Fear of unemployment and objections by vested interests
6) Absence of incentives for change
7) Absence of independent investor community and regulated financial institutions
8) Geographically and otherwise uneven development and opportunities
9) Barriers to free and equitable global trade
10) Globalization that is asymmetric, leading to "winners take all" economies

Measures for Success and Failure

1) Increase in number of areas and organizations using ICT enabled services in all areas of human development and economy

2) Greater global competitiveness of developing countries and improved economic and human development
3) Scalability and transferability of ICT enabled sustainable development projects
4) Increased number of people in the formal sector of the economy
5) Improving the quality of education at all levels from primary to tertiary with attention paid to local contexts and needs
6) Increased capital generation for development and infrastructure from the economy
7) Increased level of credit availability across socio-economic classes, extending to foreign direct investment as required
8) Increased access of modern amenities and infrastructure
9) Increased use of transparent services and increase in level of use and types of transparent transactions
10) Increase in IPR filing from developing economies
11) Economic intelligence sharing in developing countries, with reliable data

Role of ICT [1&2]

- Creation of new hitherto new industries and sources of employment
- Increasing the competitiveness of existing and traditional industries
- Providing an equitable balance to globalization
- Reduce transaction costs and related burdens on the population, freeing them to undertake productive activities

Examples of Needed Research [1&2]

1) Training packages for ICT education, for all levels of users
2) Increasing interconnectivity to and within developing countries (through new technologies such as wireless) – to allow ICT and ICT enabled/enhanced services to flourish
3) Improving software, hardware, and their integration so that solutions are robust, easy to use and maintain, and have low total costs of ownership.
4) Solutions for low-cost and secure money transfer; corresponding systems for financial credit and risk management

Alienation, Empowerment, and Governance

Alienation Issues and Empowerment [1]

Overview

The 20th century saw dramatic changes in social institutions and hierarchies, and technologies that shrank distances were cited as a major factor. While in the past this was transportation, it is now instantaneous communications technologies driving such changes.

ICT has been described as a great equalizer, if not a democratizer

ICT can be a powerful means for empowerment, especially for women and minorities. Earlier technologies for information dissemination, such as the radio, were extensions of traditional information networks, with a centralized "authority" spreading information. The Internet can fundamentally alter this balance of power, allowing new and multiple layers of interactions between individuals and groups. Giving stakeholders a voice is more than a manifestation of empowerment. It also relates to participation and efficiency – many people are outside modern service delivery systems, and they often don't know their rights or what is meant to be available from public and private providers.

Lack of empowerment and opportunities can be a driver for alienation, which might result in increased anti-social tendencies. This is a particular challenge considering most developing countries have a population pyramid with a very large number of youths, who can learn of and perceive greater disparity than ever before due to ICT and the media.

However, the more chronic issue than extreme alienation is the subtle alienation of many segments of the population, especially as relates to issues of identity and diversity. There are many cultural divides, such as gender, rural/urban, religion, age, etc. Exacerbating this is the very large increase in migration, both within and across countries, especially from developing countries to developed. International migration and changes in population makeup themselves are driven by underlying demographic changes. Not only is the population growth rate of many OECD countries very low, within these the immigrant communities often have high birth rates, at least for one generation. If we consider the various dimensions of disempowerment and alienation, the exclusion is often not explicit, but places one group at a social, economic, religious and political disadvantage. One example is the unavoidable integration faced by many communities (Table 15).

Region or Group	Number of spoken languages	Population with access to education in mother tongue in 2000	Total population (millions)
Sub-Saharan Africa	2,632	13%	641
East Asia and the Pacific	2,815	62%	1,918
South Asia*	811	66%	1,480
Central and Eastern Europe and the CIS	625	74%	409
High-Income OECD	1,299	87%	912
Latin America and the Caribbean	1,086	91%	530

Source: "Human Development Report 2004 – Comments and Contributions from SIL" (2004)

* Editors' note: South Asia has many more languages and dialects than indicated—India alone cites some 2,000—but many might be geographically limited or considered similar enough to be amalgamated.

Table 15: Population Lacking Access to Primary Education in their Mother Tongue

The UNDP Human Development Report 2004 extensively deals with the issue of cultural liberty, laying to rest several myths regarding cultural identity, peace and development:

- *Myth 1*. People's ethnic identities compete with their attachment to the state, so there is a trade-off between recognizing diversity and unifying the state.
- *Myth 2*. Ethnic groups are prone to violent conflict with each other in clashes of values, so there is a trade-off between respecting diversity and sustaining peace.
- *Myth 3*. Cultural liberty requires defending traditional practices, so there could be a trade-off between recognizing cultural diversity and other human development priorities such as progress in development, democracy and human rights.
- *Myth 4*. Ethnically diverse countries are less able to develop, so there is a trade-off between respecting diversity and promoting development.
- *Myth 5*. Some cultures are more likely to make developmental progress than others, and some cultures have inherent democratic values while others do not, so there is a trade-off between accommodating certain cultures and promoting development and democracy.

Governance and e-Governance [2]

Overview

Governance occurs within a framework that is both formal (legislated/statutory) and implicit (socio-cultural norms). In addition to "good governance" citizens require complementary support from an independent judiciary, a free press, land reforms, etc., and also seek a greater say in their future (democracy).

E-governance is a much talked about application of ICT, and it holds great promise. One aspect of e-governance is the computerization of government activities, both for internal efficiency and for increasing the ability of citizens to receive information, especially under a "single window." Computerized land records in parts of India, e.g., the *Bhoomi* project, have reduced the costs of transactions down to cents, instead of the many dollars (and days) citizens used to spend before. A second and related aspect is the establishment of linkages and connections between citizen-government as well as citizen-citizen. This means not only can they receive a particular form or document with ease, they can also participate in decision-making and provide feedback to the government.

E-governance faces many difficulties, and, though project success rates might have improved over time (and there is enormous variance between countries), as per one study as low as only 15% of e-government for development projects succeed,[53] with little post-project analysis or contribution to the state of knowledge. At the Washington Workshop, several developing country participants spoke about their lack of infrastructure—even as senior government officials, they lacked appropriate hardware or a government intranet. Even if there were hardware, the data (content) is not computerized. Implementing such changes requires not only resources, but also a willingness to share information and accept transparency as an essential element of good governance.

Governments should continue with appropriate e-governance programs even if their citizens have limited ICT access

As is the case with e-commerce, e-governance is also limited by infrastructure, especially amongst end-users. It is interesting to compare what the Government's e-governance efforts are, independent of end-user facilities (Table 16). We can note that several Latin American countries (especially Chile and Mexico) score highly in e-governance ratings. One takeaway would be for governments worldwide to continue their e-governance programs, without waiting for citizens to become wired and ready to demand such services.

[53] "Most eGovernment-for-Development Projects Fail: How Can Risks be Reduced?" John Heeks (2003). Institute for Development Policy and Management, University of Manchester, Working Paper 14.

In fact, the desire of citizens to avail of improved government and social services can become the so-called "killer app" driving demand for ICT. However, ICT-based efforts must not come at the expense of traditional service delivery mechanisms, considering the majority of citizens still lack ICT access.

E-Government Readiness Index[a]			Web Measure Index[b]			E-participation Index[c]		
1	United States	0.9132	*1*	United States	1.0000	*1*	United Kingdom	1.000
2	Denmark	0.9047	*2*	United Kingdom	0.9730	*2*	United States	0.934
3	United Kingdom	0.8852	*3*	Singapore	0.9691	*3*	Canada	0.902
4	Sweden	0.8741	*4*	Republic of Korea	0.9459	*4*	Singapore	0.836
5	Republic of Korea	0.8575	*5*	Denmark	0.9344	*5*	Netherlands	0.803
6	Australia	0.8377	*6*	Chile	0.8842	*6*	Mexico	0.770
7	Canada	0.8369	*7*	Canada	0.8726	*7*	New Zealand	0.770
8	Singapore	0.8340	*8*	Australia	0.8301	*8*	Republic of Korea	0.770
9	Finland	0.8239	*9*	Finland	0.8069	*9*	Denmark	0.738
10	Norway	0.8178	*10*	Germany	0.7954	*10*	Australia	0.672
11	Netherlands	0.8026	*11*	Mexico	0.7838	*11*	Estonia	0.639
12	Germany	0.7873	*12*	Sweden	0.7722	*12*	Colombia	0.623
13	New Zealand	0.7811	*13*	Belgium	0.7722	*13*	Belgium	0.607
14	Iceland	0.7699	*14*	New Zealand	0.7413	*14*	Chile	0.607
15	Switzerland	0.7538	*15*	Malta	0.7375	*15*	Germany	0.590
16	Belgium	0.7525	*16*	Netherlands	0.7181	*16*	Finland	0.574
17	Austria	0.7487	*17*	Estonia	0.6988	*17*	Sweden	0.574
18	Japan	0.7260	*18*	Austria	0.6988	*18*	France	0.459
19	Ireland	0.7058	*19*	Israel	0.6911	*19*	Malta	0.459
20	Estonia	0.7029	*20*	Norway	0.6873	*20*	Austria	0.443
21	Malta	0.6877	*21*	Ireland	0.6564			
22	Chile	0.6835	*22*	Argentina	0.6429			
23	Israel	0.6805	*23*	Columbia	0.6409			
24	France	0.6687	*24*	Brazil	0.6371			
25	Luxembourg	0.6600	*25*	Japan	0.6293			
	Average	0.7798						
	World Average	0.4127						
	North America	0.8751						
	Europe	0.5866						
	South and Eastern Asia	0.4603						
	South and Central America	0.4558						
	Caribbean	0.4106						
	Oceania	0.3006						
	Africa	0.2528						

Source: UN Global E-Government Readiness Report 2004: Towards Access for Opportunity

[a] Measure of e-governance readiness spanning users, infrastructure, and government's on-line activity

[b] Similar to [a] but excludes access measures (thus more a function of government actions)

[c] Measure of "usefulness" of e-government services and how frequently they are available

Table 16: E-government Readiness Indices 2004. The Chilean Government does well in offering e-governance, independent of relatively lower connectivity, and Mexico's citizens find value from the available e-government services.

Challenges [1&2]

1) Increase transparency in governance; reduce transaction costs
2) Enhance citizen participation (local and national policy making, Elections and polls), reducing vagaries of the process and opportunities for manipulation or biasing
3) Reduce the Digital Divide (geographic, socio-economic status, age and gender)
4) Allow for open discussion of governmental goals, strategies, targets and processes
5) Foster free, fair, and enlightened media
6) Increase co-ordination among local/regional/national government agencies
7) Develop appropriate legal systems to legitimize ICT enabled services
8) Allow migration paths and hybrid systems that maintain consistency between electronic and physical information (such as records)
9) Ensure security and privacy of information

Barriers [1&2]

1) Governmental inertia against innovation, modernization, or adapting
2) Presence of vested interests interfering with government and other institutions effecting changes
3) Lack of infrastructure and support systems within the Government and for access by end-users
4) Lack of access to relevant information in local and regional languages
5) Rapid obsolescence of hardware and software products resulting in high costs and continual retraining; incompatible and non-integrated ICT platforms
6) Deployment of technology or other changes without an integrated assessment of the relevant issues and opportunities
7) Lack of transparency in governmental transactions
8) Lack of a legal framework for ICT based commerce and governance
9) Lack of communications or common base between bureaucrats, technologists and customers of ICT services that hinders collaboration
10) Limited democratization of information dissemination

Measures for Success and Failure [1&2]

1) Democratization of information dissemination
2) Increased voter registration/participation in polls and reduction in voter fraud
3) Increased participation of women in all sectors of human and economic development
4) Inclusiveness of persons with disabilities and functional illiterates
5) Increased involvement of young people in education and services
6) Increased delivery of Government services online (local, regional, and national services)
7) Increased efficiency (time and quality) of government services
8) Greater availability and use of ombudsmen to all sectors of society to ensure good and fair governance
9) Increased level of IT education among bureaucrats
10) Enhanced number of communities connected by knowledge networks for economic and human development

Role of ICT [1&2]

- Increasing connections between citizens and citizens to institutions (including the government)
- Improving governance through streamlined, hassle-free interactions, with transparency in decision-making
- Providing a voice for the underrepresented and alienated

ICT can be an equalizer, making more people producers of content and information than mere consumers. With a little effort, this can include minorities and other underrepresented segments of society. This fundamental shift in terms of who can impart information requires building awareness among the population, who in many regions today receive their information from limited sources (because of media consolidation and/or governmental control).

ICT can also help in *rapid* dissemination of information (warnings) under emergency or disaster conditions, such as probable earthquakes, storms, or floods. While some of this is done today through television and radio, purpose-built systems have been proposed, especially for location-specific scenarios, such as Tsunamis.

Examples of Needed Research [1&2]

1) IT solutions that can facilitate and integrate all levels of data collection, storage, analysis, and dissemination – ranging from large (governmental) to micro (grassroots) systems
2) Technologies to maintain and enhance privacy and control over personal information

ICT for SD – Linking Needs to Solutions

The integration of ICT into all aspects of human activity is inexorable. Governments, service providers, and companies are adopting such technologies, often unbeknownst to their end-users or clients. What was decades ago the wondrous act of listening to voices from miles away (radio) has become replaced by even children accepting (and demanding) instantaneous interaction at almost any location (mobile telephony). The challenge for professionals is to link ICT to specific human and economic development needs, as was attempted in the Workshops. Table 17 summarizes the Workshop findings and recommendations for ICT research as linked to development needs.

Thematic Area	Group/Sub-Group	Development Need	Key Recommended Research	*Primary ICT Mapping:* Sensors (S) Communication (C) Databases/Information Systems (DB/IS) Controllers/Actuators/ Effectors (CTRL) Human-Computer Interaction (HCI)
Infrastructure	Water	Better models and assessment of supply and quality	Low-cost sensors; GIS models, data dissemination solutions, and integration into user frameworks	S, C, DB/IS, HCI
	Energy	Improved measurement, theft-control, and control (including demand-side management)	Tamper-proof digital electricity meters with control and communications, with integration into efficient end-use appliances for load control	S, C, DB/IS, CTRL
	Transportation	Optimization of public and private transport along with enhanced safety (e.g., trains)	Integration of sensors, GIS, GPS, and other technologies	S, C, DB/IS, HCI
Basic Human Development	Food and Agriculture	Optimize inputs to the soil and improve productivity; Improve farmers' stake in the supply-chain	Sensors and Information Systems for optimizing irrigation [e.g., drip irrigation], fertilizers, pesticides, etc.; developing accessible and affordable solutions for access to market, weather, and other information	S, C, DB/IS, CTRL, HCI
	Healthcare	Improve delivery of healthcare services; make systems more participatory	ICT solutions integrated with existing systems; develop easy-to-use and robust interfaces and platforms	C, DB/IS, HCI
	Education	Improve literacy and student skills; meet varying needs of different levels of students (age, gender, specialization, etc.)	Easy-to-use and scalable solutions for education; customized content and delivery systems, with feedback	C, DB/IS, HCI
Economic Growth and Employment	ICT-based and ICT-enabled job creation and poverty reduction	Improve awareness and skills in ICT; integrate ICT into economic activity; create solutions for low-cost money transfer, (micro)credit, and risk management	Easy-to-use and scalable solutions for education; (open) easy-to-implement standards for ICT integration; secure, flexible and inexpensive systems to manage and move money	C, DB/IS, HCI
Alienation, Empowerment, and e-Governance	Alienation issues and empowerment; e-Governance	Easier sharing of information (within norms of privacy and individual control)	Solutions that make it easy to create, monitor, search, and apply information, while maintaining end-user privacy and control	C, DB/IS, HCI

Table 17: Mapping of Development Needs to R&D Requirements in ICT, Based on Bangalore Workshop Deliberations

4 Where do we go from here?

Meeting the Millennium Development Goals is a daunting task, even with the benefits of ICT. In fact, ICT as it stands today is not well engineered for sustainable development. Making it appropriately scaled, budgeted, and usable will require extensive research and development. In this chapter, we make the case that to meet the MDGs, ICT for SD requires a serious commitment as a globally supported enterprise. In order to define the scope of this enterprise, we discuss research ideas and suggestions for testbed demonstrations, the need for metrics for ICT for SD, the role of stakeholders, and a new R&D model that adds feedback and stakeholder participation.

ICT for SD R&D – Projects and Testbeds

Table 17 summarizes a number of specific examples of suggested research and development. Workshop participants recognized that undertaking such research would require extensive time, effort, and funding. At a macro-level, these R&D tasks can be can be broken into:

- Short-term agenda – ICT exists and needs to be applied
- Medium-term agenda – ICT needs modification to be applicable
- Long-term agenda – Appropriate ICT needs to be developed

Some of these tasks are discussed below in more detail.

1. *Make ICT universally available, accessible, and affordable.* Ending the digital divide should be a policy imperative. At the very least, basic information, primary educational programs and government services should be accessible to all citizens within convenient distance, at zero or near zero cost.

   In addition to connectivity, research is required to make ICT accessible for those who do not use the major languages (esp. English) and/or have limited literacy. In addition to innovations based on language translation and speech recognition technologies, creation of localized content will help spur the user demand for ICT.

   a. *Village Connectivity Networks.* The combination of wireless access with optical fibers can be cost-effective for improving connectivity. Detailed studies at Carnegie Mellon suggest that such leapfrog design options could provide broadband connectivity for the majority of Africans within walking or cycling distance for roughly $1 billion one-time capital costs.[54] Several clusters of villages can be targeted for such connectivity experiments to prove the concept, but wireless innovations (including modified WiFi, WiMax, etc.) need to be deployed in the field to assess their technical and business viability.

[54] This excludes end-user equipment such as computers or receivers (modems). Further details available online at http://www.contrib.andrew.cmu.edu/~tongia/FiberAfrica--ending_a_digital_divide.pdf

b. *Advanced Wireless Technologies.* Regulatory hurdles often limit the potential of new wireless technologies. There is a need to develop software defined radios, which can operate in any frequency, or even "cognitive radios." [55] This versatility would help produce the global volume required for dramatically lower costs as all countries could use the same equipment. Additional research is also required into mesh networking, which can reduce uplinking costs significantly, and smart array antennas (called Multiple Input, Multiple Output – MIMO – systems) that can improve the performance manifold.

2. *Make ICT usable and applicable.* Complex systems like trucks and cars demand very little advanced skills from their users. On the other hand, end-user ICT is complex, user-unfriendly and difficult to operate and maintain. Considering even professionals struggle to use and maintain computer systems, how can we expect the archetypal village grandmother to use a computer? It needs to be made simpler and more robust, akin to a television or mobile phone.

   A way to judge the level and success of computer penetration in society is by assessing how ubiquitous it has become. Television has crossed this threshold; as have mobile phones, and computers must follow this trajectory to make an impact.

   One unanswered question is whether ICT solutions should be as powerful and general-purpose as possible, allowing vast economies of scale, utilizing shared components such as cheap memory, open software, etc., *or* should ICT solutions be as purpose-built and application–specific as possible, allowing lower production costs and easier interfaces. The growth of ICT ensures that even a "simple" PC is capable of immense processing power. However, most people only use a fraction of this capability, as is the case with many electronic devices. An intriguing possibility is for ICT developers to design distributed computing systems that can tap into such power when required, but remain simple and easy-to-use most of the time. There are a few examples of such usage from the science world where parallel processing is done using a large number of computers that have spare processing power. Specific development tasks and fields amenable for such distributed computing include healthcare/bioinformatics, supply-chain and logistical management, language translation, and multimedia processing.

3. *Integrate ICT into development issues and economic growth*. Research is needed to identify how much of a difference ICT can make in a particular field, and how much investment and other inputs are required for the field itself. For instance, Sub-Saharan agricultural productivity is tens of times lower than that of the Netherlands or Belgium. Much of that is due to the poor physical condition of the soil, which demands nutrients and water. ICT can help in choosing the appropriate crops and helping to time and optimize the inputs. It can also help the farmer receive greater value for his/her output. But, ICT alone will not improve the yield or the farmer's earnings.

   a. *Knowledge Networks.* Many information networks, though meant to benefit the end-user, are designed only to be used by professionals. This is in part due to difficulties at the end-user's end, his or her illiteracy combined with lack of connectivity. Advances in connectivity and creation of specialized knowledge networks that reach up to end-users are therefore necessary. A practical option would be through the use of intermediaries that translate information into useable formats and levels. The e-*Choupal* initiative by the Indian firm ITC provides such an example. It is essential

[55] In addition to being frequency variable and agile, cognitive radios sense their operating environment and choose the optimal band, modulation, power level, etc.

to build educational knowledge networks for anyone, anywhere, to access information in any language. Digital libraries must be expanded, with language translation capabilities.

b. *Remote and field diagnosis, leading to "Lab on a chip"*. Given the endemic nature of a number of diseases (HIV, malaria, etc.) and health conditions (anemia, malnutrition, etc.), it is important to inexpensively diagnose and monitor the vulnerable population. This is the first step to improved healthcare.

   Medical diagnostic tests are generally quite expensive. Even when diagnosed, many health conditions require regular follow-ups during treatment, notably HIV/AIDS. The only treatment, Highly Active Antiretroviral Therapy (HAART), requires regular screenings to determine the efficacy of the medicines and to check against side effects. There is a scarcity of healthcare professionals in developing countries, especially in rural areas. Here, ICT can be an invaluable tool through the development of appropriate and robust diagnostic and monitoring solutions.

c. *Micro irrigation for agriculture.* Agriculture is the primary consumer of fresh water that is in short supply in many developing countries. Learning from the experience of farmers in Australia and Israel, it is possible to optimize delivery of water and fertilizers through drip irrigation systems. This can reduce water consumption by almost 50% and improve the yield. The challenge is to make such systems robust for developing country deployment and cost-effective.

d. *Smart meters for energy and electricity.* Energy is a critical input for economic growth, especially in the form of electricity. Unfortunately, most developing countries (with some exceptions like in E. Asia) face very high transmission and distribution losses and theft, affecting the economic viability of the utilities. ICT can help reduce theft significantly with smart meters that can communicate and be controlled remotely. Such systems will also help improve the overall efficiency through options such as load control and demand side management. Given their limited deployment of metering in some regions, this represents a leap-frog opportunity for developing countries.

e. *Sensor Networks.* This catch-all term spans the range of sensors covering environmental monitoring to equipment operating conditions. The latter are widely used in industrial settings, but not so in the field because of size and robustness limitations, power requirements, connectivity shortcomings, and cost. There is a clearly defined need to make sensors relevant for sustainable development.

In addition to basic research, it is also necessary to design "test-bed" experiments that mimic field conditions to validate the scalability and viability of the solutions.

Defining the Scope of the ICT for Sustainable Development Enterprise

If one mentions ICT for Sustainable Development, there is a general tendency to associate this with digital divide issues, especially on how to make the Internet available to more people. ICT for SD is about more than mere connectivity. It is the special intersection of diverse fields of enquiry and application, spanning technology, economics, sociology, and policy, amongst others. Research in ICT for SD therefore needs legitimacy and promoters within the academic, research, and development communities. We believe that now is an

appropriate time to structure and build ICT for SD as a distinct enterprise drawing participation from technologists, social scientists, and development professionals.

ICT for SD requires global collaboration, specialized research, and testbeds, perhaps using a network of centers and institutions

Such interdisciplinary collaboration requires interaction between existing research and development institutions, as well as the creation of a network of collaborating academic institutions, national labs, development organizations, etc. Just like the Consultative Group for International Agricultural Research (CGIAR) was established by multilateral support as "a strategic alliance of members, partners and international agricultural centers that mobilizes science to benefit the poor,"[56] ICT for SD requires similar collaboration, funding, and effort. In fact, given the requirement for localization of information and feedback from end-users, it requires even deeper penetration into global societies and greater interaction amongst stakeholders.

A focused endeavor brings its own advantages such as a better stratification and synthesis of information and knowledge. This will diffuse the individual anecdotes that today clog information channels on ICT for SD, and often do not stand up to critical scrutiny or emulation.

Metrics and Rigorous Analysis

There are as many success stories in ICT for SD as there are failed projects, and we often don't know the details of the latter. Even some successes do not come up to the original expectations or they continue to depend on subsidies. At the Bangalore Workshop, Tom Kalil referred to this field as being full of "Potemkin Villages."[57] ICT for SD requires formalization of measures for success, standardization of evaluation, and rigorous critical analysis.

Analysis of ICT for SD must extend beyond single projects. The global scale of challenges requires replicability, scalability and economic sustainability. Analysis must also cover the cost-effectiveness of the solutions, including opportunity costs and alternative solutions.

Related to the issue of metrics is standardization of information and its quality. The World Wide Web has exacerbated information overload, and insufficient attention is paid to the accuracy, assumptions behind, or timeliness of the information.

Role of Stakeholders

The pantheon of stakeholders in the ICT for SD network is vast, and their linkages are many. We highlight the role of the stakeholders in the ICT and the sustainable development processes.

End-users need to integrate ICT into their personal and professional life to harness its capabilities for human development. Their needs should ultimately drive the entire development process. Of course, integration and demand is critically dependant on ICT's usability and affordability. However, all other things being equal, an informed consumer is better able to articulate his or her needs, to use ICT as given, and also apply ICT to new uses.

ICT Companies must continue to invest and innovate in ICT development for it to be applicable to SD. The challenge is one of matching investments and efforts along a

[56] CGIAR website: http://www.cigar.org

[57] Refers to a facade covering up undesirable facts or conditions.

sustainable path, avoiding booms and busts. Another difficulty is that the scale of investments varies with projects and technologies; some developments necessarily require large expenditure, especially where more basic R&D is required, such as for language translation solutions.

Companies, Corporations and Industry are natural consumers of ICT, and their use provides the volume for spreading ICT further into the market supply chain. If large companies demand electronic transactions from their suppliers/distributors/etc., even smaller companies will have to adopt ICT. In turn, they may then use ICT as an interface to their clients.

Entrepreneurs are a special case of commercial entities. In developing countries, they often focus on service delivery instead of R&D. Cable TV in India grew rapidly not merely because of the affordability of the services for consumers (initially a few dollars per month) but also because of thousands of franchisee or small-scale operators who found providing services a profitable venture. The same has been the case for many ICT kiosks worldwide and the GrameenPhone in Bangladesh.

Development Service Providers (water, electricity, etc.) are often part of the government (or private companies), but they form a distinct set of stakeholders. This group is likely to require greater assistance in using ICT than private companies or even many governments. Better provision of services will require specialized ICT solutions that are easy to implement and also politically acceptable.

Governments have an enormous role in ICT for SD, just as they have an overarching presence in most facets of development and commerce in developing countries. They not only provide many development services, including ICT services, they also set the policies that lay the ground rules for deployments. The government is also the regulator of ICT and other services, and shapes innovation and R&D in a country.

National ICT policies have often taken two somewhat distinct tracks, focusing on ICT as a sector in and of itself or focusing on ICT as an enabler. The former splits into a domestic focus (like Brazil) or an export focus (like India in the 1990s), while the latter splits into a global position focus (like Ireland) or a development goals focus (like Estonia or South Africa in the 1990s).[58]

Some professionals argue for minimal intervention from the government, especially in the software sector. However, as Joseph Stiglitz highlighted in his Keynote Address at Bangalore, the role of the government is important, covering education, infrastructure, and directed support (such as creating “islands” for export promotion, appropriate tax incentives, etc.) Public funding is typically the norm for significant “basic research” whose benefits may not be appropriable by a single firm. After all, the Internet itself came from ARPA (US Government) funding. In addition, the government should intervene where markets fail, are inefficient, or where it is socially important to intervene.

[58] “The Role of Information and Communication Technologies In Global Development: Analyses and Policy Recommendations” (2003), UN ICT Task Force Series 3, edited and with introduction by Abdul Basit Haqqani.

One important government role (which requires research determining optimal strategies) is universal service provision (of both ICT services and other development services). Some countries choose general tax funds, others establish industry-specific taxes, and some rely on extensive cross-subsidies. One promising model has been the Chilean "reverse auction" where auctions were held amongst private providers for bids for the lowest subsidy required to serve rural areas (including through pay telephones). Through this program, started in the mid-1990s, Chile went from 85% telephony access (at a community level) to 99% by 2002.[59]

Funding agencies have a vital role to play in ICT for SD research, but this is complicated by their current boundaries (i.e., basic science vs. applied research, science/engineering vs. social sciences, etc.) Linkages between different development themes further complicate funding availability (e.g, is ICT for agriculture a technical, social, or economic issue?), but this might also make it easier to secure funding from different kinds of agencies. As ICT for SD becomes a recognized discipline, different entities should fund work in this area, ideally in concert with complementary groups. It would be beneficial to have the equivalent of a DARPA for this field, an agency that funds long-term and even exploratory research. This is necessary given the inherent risks and uncertainty in basic research, and the long timeframes these would entail.

Academic Institutions can provide a steadying force given the uncertainties and unknowns in this emerging discipline. In addition to the research they specialize in, they can provide unbiased and public analyses of various technologies. Unlike companies, academic research results are generally shared openly. They can also help steer the directions of the field, and crystallize challenges and opportunities in the field. Often universities establish exclusive research and development centers or institutes to explore new and emerging areas of enquiry. ICT for SD is now a fertile discipline for such initiatives. These would provide the scale and critical mass required for long-term analysis and wide-scale testbeds and demonstrations. Such centers would also enhance the training of multidisciplinary professionals, with programs integrating facets such as technology, policy, finance, regulation, and ethics.

New ICT-SD Model: Need for Research, Development, & Demonstration (RD&D)

Business as usual models, with their attendant trickle-down approach, may not help meet the MDGs, especially in the proposed timeframes. New models of research and sharing research findings (intellectual property) are required to spur R&D and also prevent people from reinventing the wheel. Suggestions include clearinghouses and portals, which should do more than store information or allow simple searches.

At a business end, new models, with appropriate regulatory clearances, will be required for innovators and entrepreneurs. Flexible (micro) financing and micro-franchising models will also be important for achieving scalability. Presently, there are no accepted best practice models for either human development or for ICT for sustainable development, and there are wide variances in local social and cultural norms and requirements. Based on sharing experiences, researchers, development specialists, and practitioners can build solutions that are contextually relevant.

The research challenges in ICT for SD can be overwhelming, given the large human development needs these are trying to address. There have been multiple studies and recommendations on how to do IT research to make it more societally relevant. For

[59] "ICT and MDGs: World Bank Group Perspective," December 2003

example, in the US National Academies report *Making IT Better: Expanding Information Technology Research to Meet Society's Needs* (2000), the authors highlighted the need for new specialization, collaboration, and scaling. However, these recommendations have not yet been adopted. In particular, the issue of funding remains a challenge, made worse by the bursting of the IT “bubble” in the early part of this decade.

Who will pay for the research? This is not merely the age-old question associated with all research (and heightened by the target – developing countries). This question relates to the different stages of research required for successful ICT for sustainable development. ICT-SD is not simply an issue of making ICT cheaper and faster, and then letting its effects trickle down until there is widespread usage. Rather, ICT that is available, accessible, and affordable requires interaction between the stakeholders, with feedback loops that are largely missing today (Figure 13).

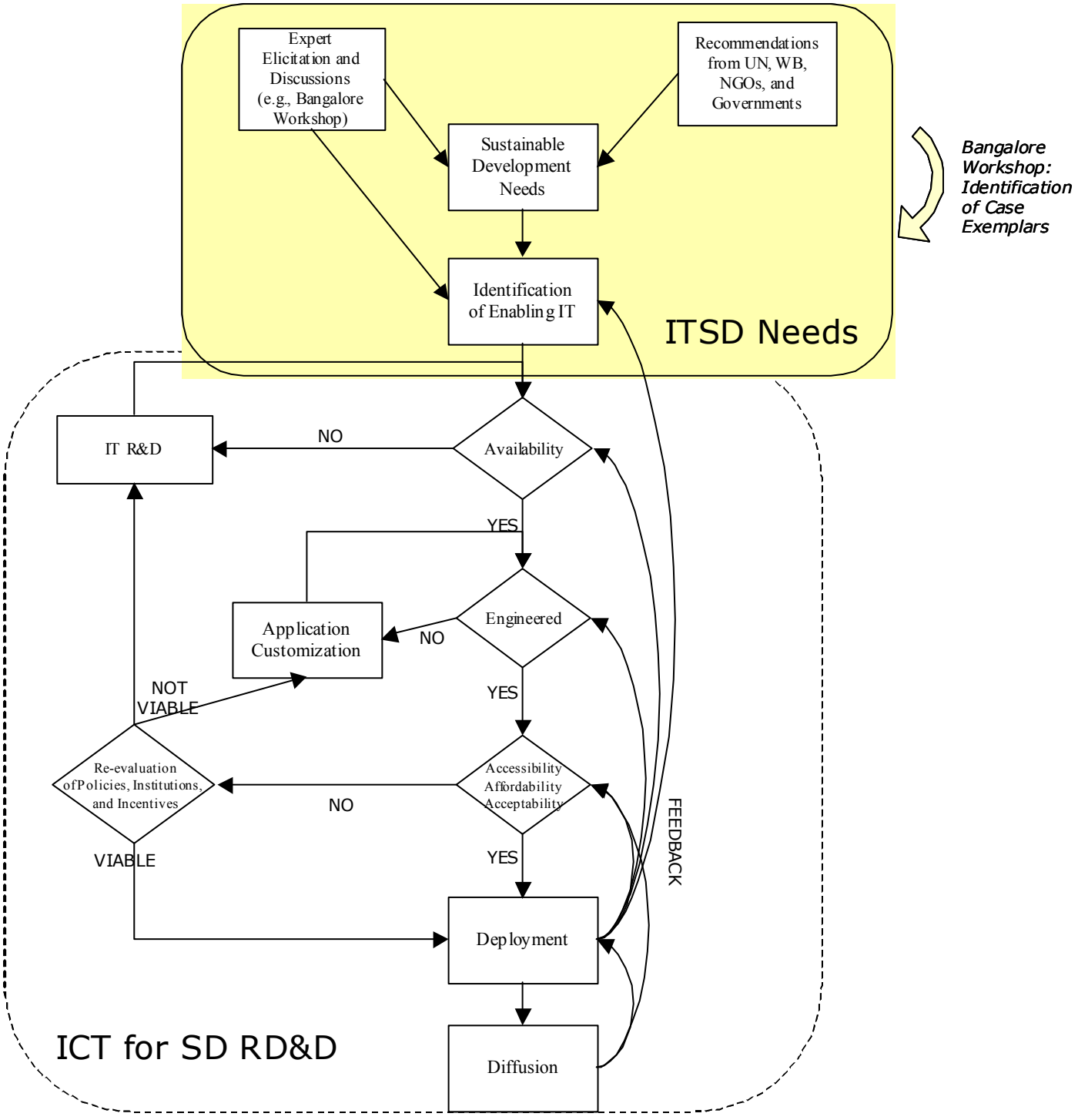


Figure 13: Process Flow Diagram for ICT for Sustainable Development. Issues of appropriateness, affordability, and impact are central to ICT research and design, instead of merely affecting penetration and deployment.

Successful ICT for SD requires feedback loops between stakeholders at all stages of development

Technical bodies and funding agencies such as Science Foundations concern themselves largely with technology issues. Development Agencies focus mainly on development, and ICT is not fully internalized into their planning, projections, and policies for development. We propose that traditional "linear" R&D needs to be superceded by RD&D – Research,

Development, and Demonstration. Demonstration as we propose is not simply a pilot project, but deployment in the field, demonstrating scalability and viability. This last step would ensure human, social, and economic factors (such as cultural acceptability, business models, etc.) are part of the entire development process. Otherwise, the outputs of ICT face major hurdles in their deployment.

Challenges and Lessons Learned

At the Washington and Bangalore Workshops, Carlos Braga presented some cautionary advice to technologists, who often are "techno-optimists": expect the unexpected, and move beyond lab or pilot projects.

Other key challenges and issues discussed at the Workshops include:

- Scalability/replicability, combined with viability, is a key metric for success. Extrapolation, even from real-world deployments, can be misleading or erroneous.
- ICT is good for enhancing development programs, but frequently solutions are geared to supercede existing programs. The focus has often remained exclusively on ICT instead of enhanced delivery of services.[60] ICT is a means, and not an end.
- Capacity building and education are keys to inclusiveness and sustainable demand.
- ICT for development programs cannot be established as charity; while subsidies may be required, long-term viability is key to replicability, and thus, global penetration.
- The market will not necessarily provide societally optimal price and incentive signals, and one should not wait for trickle down growth.
- The elite and upwardly mobile have exit strategies around poor services, through options such as private healthcare and education, diesel generation, bottled water, etc. These further remove market demand for improved services. Even the poor, in spite of the high costs, opt for such options demonstrating their willingness to pay for services they consider important.
- ICT solutions must be shared – we don't want to reinvent the wheel. Often, different countries, industries, or funding agencies expend resources testing the same underlying technology.
- Will ICT create new divides, or exacerbate existing ones?

The workshops have raised more questions than answers. The intersection between ICT and development is indeed complex. The stakeholders are many and diverse, the metrics for assessment are unavailable, and the seamless integration of ICT with other tools for development has not yet taken place.

We see the contribution of the Workshops at two levels. At the first level, we have identified specific research areas based on the intersection of technologies and development needs, bringing together experts in all the appropriate disciplines and domains. At another level, we have created a framework for ICT to help address the Millennium Development Goals by identifying the relationship between technologies, example applications and potential research areas. We propose a new paradigm for research (which we term Research,

[60] "Rethinking the European ICT Agenda: Ten ICT-breakthroughs for reaching Lisbon goals" (August 2004), prepared by PriceWaterhouseCoopers for the Dutch Ministry of Economic Affairs, highlights this issue, as well as a number of policy breakthroughs required to reaching the Lisbon goals. The Lisbon goals were formulated in March 2000 by the European Council, stating their ambition to become 'the most competitive and dynamic knowledge-based economy in the world by 2010.' Similar cooperative targets and agreements are required for ICT for SD.

Development, and Demonstration – RD&D) that is sensitive to the goals of the stakeholders and the efficacy of development.

A knowledge-based economy requires transparency and easy exchange of ideas in a public or semi-public space. The goal is making technology ubiquitous enough for it to become integral to people's daily lives. The Workshops are, we hope, a step in making information and communication technologies an integral part of sustainable development.

Appendices

Appendix 1: Targets of the Millennium Development Goals

Target 1 Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day.

Target 2 Halve, between 1990 and 2015, the proportion of people who suffer from hunger.

Target 3 Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling.

Target 4 Eliminate gender disparity in primary and secondary education, preferably by 2005, and to all levels of education no later than 2015.

Target 5 Reduce by two thirds, between 1990 and 2015, the under-five mortality rate.

Target 6 Reduce by three quarters, between 1990 and 2015, the maternal mortality ratio.

Target 7 Have halted by 2015 and begun to reverse the spread of HIV/AIDS.

Target 8 Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases.

Target 9 Integrate the principles of sustainable development into country policies and programs and reverse the losses of environmental resources.

Target 10 Halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation.

Target 11 Have achieved by 2020 a significant improvement in the lives of at least 100 million slum dwellers.

Target 12 Develop further an open, rule-based, predictable, non-discriminatory trading and financial system. It includes a commitment to good governance, development, and poverty reduction – both nationally and internationally.

Target 13 Address the special needs of the least developed countries. Includes: tariff and quota-free access for least-developed countries' exports; enhanced program of debt relief for HIPCs (Heavily Indebted Poor Countries) and cancellation of official bilateral debt; and more generous ODA (Official Development Assistance) for countries committed to poverty reduction.

Target 14 Address the special needs of landlocked countries and small island developing States (through the Program of Action for the Sustainable Development of Small Island Developing States and the outcome of the twenty-second special session of the General Assembly).

Target 15 Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term.

Target 16 In cooperation with developing countries, develop and implement strategies for decent and productive work for youth.

Target 17 In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries.

Target 18 In cooperation with the private sector, make available the benefits of new technologies, especially information and communications.

Appendix 2: ICT statistics – Digital Access Indicator (DAI) Metric [ITU – Dec. 2003]

		Sub lines p. 100 inhab.	Mobile sub. p. 100 inhab.	Internet tariff as % of GNI	Adult Literacy	School enrollment	Int'l Internet bandwidth p. 100 inhab.	Broad band subscribers p. 100 inhab.	Internet users p. 100 inhab.	INFRA-STRUCTURE	AFFORD-ABILITY	KNOW-LEDGE	QUALITY	USAGE	DAI
	HIGH														
1	Sweden	65.2	88.9	1.1	98.5	113.0	10,611.2	8.0	57.3	0.94	0.99	0.99	0.64	0.67	0.85
2	Denmark	57.4	83.2	0.7	99.5	98.0	20,284.9	8.2	51.2	0.89	0.99	0.99	0.66	0.60	0.83
3	Iceland	51.9	90.7	0.9	98.5	91.0	236.5	8.2	64.9	0.89	0.99	0.96	0.50	0.76	0.82
4	Korea (Rep.)	48.6	67.9	1.2	97.9	91.0	361.5	21.9	55.2	0.74	0.99	0.96	0.74	0.65	0.82
5	Norway	50.4	84.3	0.8	99.5	98.0	4,981.6	4.5	50.2	0.84	0.99	0.99	0.55	0.59	0.79
6	Netherlands	48.5	74.5	1.2	99.0	99.0	10,327.5	6.6	50.6	0.78	0.99	0.99	0.61	0.60	0.79
7	Hong Kong, China	56.6	91.6	0.2	93.5	63.0	1,866.8	14.6	43.0	0.93	1.00	0.83	0.68	0.51	0.79
8	Finland	46.3	84.5	1.1	98.5	103.0	3,185.5	5.3	50.9	0.81	0.99	0.99	0.55	0.60	0.79
9	Taiwan, China	57.4	106.4	0.7	96.0	93.0	658.6	9.4	38.3	0.98	0.99	0.95	0.56	0.45	0.79
10	Canada	61.3	37.7	0.7	98.5	94.0	2,841.8	11.1	51.3	0.69	0.99	0.97	0.64	0.60	0.78
11	United States	65.0	47.3	0.5	98.5	94.0	1,323.6	6.9	55.1	0.74	0.99	0.97	0.54	0.65	0.78
12	United Kingdom	53.4	83.9	1.1	98.5	112.0	5,402.8	3.1	42.2	0.86	0.99	0.99	0.53	0.50	0.77
13	Switzerland	55.7	78.4	0.7	98.5	88.0	8,991.7	6.2	34.9	0.86	0.99	0.95	0.60	0.41	0.76
14	Singapore	46.2	79.4	0.6	92.5	75.0	1,414.0	6.5	50.3	0.78	0.99	0.87	0.54	0.59	0.75
15	Japan	47.7	63.7	0.8	99.5	83.0	237.7	6.2	54.5	0.72	0.99	0.94	0.47	0.64	0.75
16	Luxembourg	53.4	105.3	0.9	98.5	73.0	3,271.7	1.3	36.7	0.94	0.99	0.90	0.48	0.43	0.75
17	Austria	40.4	80.9	1.7	99.5	92.0	4,421.6	5.5	40.9	0.74	0.98	0.97	0.56	0.48	0.75
18	Germany	48.2	72.7	0.7	99.5	89.0	3,155.8	3.9	41.2	0.76	0.99	0.96	0.52	0.48	0.74
19	Australia	51.7	64.0	1.1	98.5	114.0	533.9	1.8	48.2	0.75	0.99	0.99	0.42	0.57	0.74
20	Belgium	42.4	78.6	1.5	98.5	107.0	8,121.4	8.4	30.9	0.75	0.99	0.99	0.63	0.36	0.74
21	New Zealand	45.3	62.2	1.1	99.0	99.0	584.7	1.4	45.7	0.69	0.99	0.99	0.42	0.54	0.72
22	Italy	41.5	92.5	1.0	98.5	82.0	1,179.8	1.9	34.7	0.81	0.99	0.93	0.45	0.41	0.72
23	France	52.0	64.7	0.8	98.5	91.0	3,269.8	2.8	31.4	0.76	0.99	0.96	0.51	0.37	0.72
24	Slovenia	44.0	83.5	3.1	99.6	83.0	539.7	2.8	37.6	0.78	0.97	0.94	0.44	0.44	0.72
25	Israel	43.5	95.5	2.1	95.1	90.0	213.7	2.0	30.1	0.84	0.98	0.93	0.39	0.35	0.70
	UPPER														
26	Ireland	40.1	76.3	1.4	98.5	91.0	3,434.5	0.3	27.1	0.72	0.99	0.96	0.47	0.32	0.69
27	Cyprus	62.4	58.5	1.7	97.2	74.0	236.4	0.8	29.4	0.79	0.98	0.89	0.38	0.35	0.68
28	Estonia	35.1	65.0	3.9	99.8	89.0	409.6	3.4	32.8	0.62	0.96	0.96	0.44	0.39	0.67
29	Spain	44.6	80.1	1.7	97.7	92.0	1,112.7	3.0	15.2	0.77	0.98	0.96	0.47	0.18	0.67
30	Malta	52.3	69.9	2.3	92.3	76.0	391.4	4.5	20.9	0.79	0.98	0.87	0.46	0.25	0.67
31	Czech Republic	33.4	84.9	4.5	98.5	76.0	2,189.1	0.2	25.6	0.70	0.96	0.91	0.45	0.30	0.66
32	Greece	52.4	84.5	2.4	97.3	81.0	222.0	0.0	15.5	0.86	0.98	0.92	0.36	0.18	0.66
33	Portugal	35.4	81.9	2.3	92.5	93.0	386.2	2.5	19.2	0.71	0.98	0.93	0.42	0.23	0.65
34	United Arab Emirates	34.2	75.9	0.8	76.7	67.0	339.1	0.5	36.7	0.66	0.99	0.73	0.39	0.43	0.64
35	Macao, China	39.8	62.5	1.0	91.3	55.0	489.1	3.8	26.0	0.64	0.99	0.79	0.45	0.31	0.64
36	Hungary	32.6	67.6	4.1	99.3	82.0	1,048.3	1.1	15.8	0.61	0.96	0.94	0.44	0.19	0.63
37	Bahamas	40.6	39.0	2.0	95.5	74.0	464.7	6.3	19.2	0.53	0.98	0.88	0.49	0.23	0.62
38	Bahrain	26.3	58.3	4.1	87.9	81.0	292.4	0.7	24.7	0.51	0.96	0.86	0.38	0.29	0.60
39	St. Kitts and Nevis	50.0	31.9	4.2	97.8	70.0	42.2	1.1	21.3	0.58	0.96	0.89	0.32	0.25	0.60
40	Poland	29.5	36.3	4.1	99.7	88.0	163.6	0.0	23.0	0.43	0.96	0.96	0.35	0.27	0.59
41	Slovak Republic	26.8	54.4	6.3	100.0	73.0	1,516.0	0.0	16.0	0.50	0.94	0.91	0.43	0.19	0.59
42	Croatia	39.0	53.5	4.4	98.4	68.0	41.2	0.3	18.0	0.59	0.96	0.88	0.31	0.21	0.59
43	Chile	23.0	42.8	6.1	95.9	76.0	131.6	1.3	23.8	0.41	0.94	0.89	0.36	0.28	0.58
44	Antigua & Barbuda	47.8	32.1	2.8	86.6	69.0	359.0	0.0	12.8	0.56	0.97	0.81	0.38	0.15	0.57
45	Barbados	47.9	19.7	3.2	99.7	89.0	24.2	0.0	11.2	0.50	0.97	0.96	0.28	0.13	0.57
46	Malaysia	19.3	37.7	2.9	87.9	72.0	53.8	0.1	32.0	0.35	0.97	0.83	0.31	0.38	0.57
47	Lithuania	26.4	47.6	11.2	99.6	85.0	94.8	0.6	14.5	0.46	0.89	0.95	0.34	0.17	0.56
48	Qatar	28.9	43.8	0.9	81.7	81.0	254.1	0.0	11.5	0.46	0.99	0.81	0.37	0.14	0.55
49	Brunei Darussalam	25.1	38.9	1.4	91.6	83.0	170.5	0.0	9.9	0.40	0.99	0.89	0.35	0.12	0.55
50	Latvia	30.1	39.4	20.0	99.8	86.0	181.6	0.4	13.3	0.45	0.80	0.95	0.36	0.16	0.54
51	Uruguay	28.0	19.3	7.3	97.6	84.0	128.9	0.0	13.6	0.33	0.93	0.93	0.34	0.16	0.54
52	Seychelles	26.2	53.9	16.9	91.0	79.0	72.3	0.1	14.1	0.49	0.83	0.87	0.32	0.17	0.54
53	Dominica	33.3	13.1	6.3	96.4	65.0	70.2	0.8	17.5	0.34	0.94	0.86	0.33	0.21	0.54
54	Argentina	21.9	17.8	3.9	96.9	89.0	149.6	0.3	11.2	0.27	0.96	0.94	0.35	0.13	0.53
55	Trinidad & Tobago	25.0	27.8	2.5	98.4	67.0	73.8	0.0	10.6	0.35	0.98	0.88	0.32	0.12	0.53
56	Bulgaria	36.8	33.3	8.3	98.5	77.0	10.1	0.0	8.1	0.47	0.92	0.91	0.25	0.10	0.53
57	Jamaica	17.2	53.5	16.9	87.3	74.0	28.0	1.0	22.9	0.41	0.83	0.83	0.30	0.27	0.53
58	Costa Rica	25.1	11.1	7.6	95.7	66.0	114.7	0.0	19.3	0.26	0.92	0.86	0.34	0.23	0.52

		Sub lines p. 100 inhab.	Mobile sub. p. 100 inhab.	Internet tariff as % of GNI	Adult Liter-acy	School enroll-ment	Int'l Internet bandwidth p. 100 inhab.	Broad band subscribers p. 100 inhab.	Internet users p. 100 inhab.	INFRA-STRUCTURE	AFFORD-ABILITY	KNOW-LEDGE	QUALITY	USAGE	DAI
59	St. Lucia	32.0	8.9	6.9	90.2	82.0	93.8	0.0	11.3	0.31	0.93	0.87	0.33	0.13	0.52
60	Kuwait	20.4	51.9	2.0	82.4	54.0	25.0	0.0	10.6	0.43	0.98	0.73	0.28	0.12	0.51
61	Grenada	31.6	7.1	7.6	94.4	63.0	37.7	0.5	14.2	0.30	0.92	0.84	0.31	0.17	0.51
62	Mauritius	27.0	28.9	4.7	84.8	69.0	28.1	0.0	9.9	0.37	0.95	0.80	0.29	0.12	0.50
63	Russia	23.9	12.0	5.6	99.6	82.0	61.2	0.0	4.1	0.26	0.94	0.94	0.32	0.05	0.50
64	Mexico	14.6	25.3	4.6	91.4	74.0	56.9	0.2	9.8	0.25	0.95	0.86	0.32	0.12	0.50
65	Brazil	22.3	20.1	11.8	87.3	95.0	53.7	0.4	8.2	0.29	0.88	0.90	0.32	0.10	0.50
	MEDIUM														
66	Belarus	29.9	4.7	11.3	99.7	86.0	4.4	0.0	8.2	0.27	0.89	0.95	0.22	0.10	0.49
67	Lebanon	19.9	22.7	11.1	86.5	76.0	17.6	1.0	11.7	0.28	0.89	0.83	0.29	0.14	0.48
68	Thailand	10.4	26.0	4.2	95.7	72.0	16.3	0.0	7.8	0.22	0.96	0.88	0.27	0.09	0.48
69	Romania	18.7	22.9	16.4	98.2	68.0	87.2	0.1	8.1	0.27	0.84	0.88	0.33	0.09	0.48
70	Turkey	26.9	33.6	9.5	85.5	60.0	10.6	0.0	7.0	0.39	0.90	0.77	0.25	0.08	0.48
71	TFYR Macedonia	27.1	17.7	13.3	94.0	70.0	24.2	0.0	4.8	0.31	0.87	0.86	0.28	0.06	0.48
72	Panama	12.4	19.2	10.7	92.1	75.0	210.1	0.0	4.1	0.20	0.89	0.86	0.36	0.05	0.47
73	Venezuela	11.2	25.5	5.7	92.8	68.0	27.3	0.3	5.0	0.22	0.94	0.85	0.29	0.06	0.47
74	Belize	12.4	20.4	23.1	93.4	76.0	181.8	0.0	11.9	0.21	0.77	0.88	0.36	0.14	0.47
75	St. Vincent	23.4	8.5	9.5	88.9	58.0	34.2	0.9	6.0	0.24	0.91	0.79	0.31	0.07	0.46
76	Bosnia	22.0	18.3	6.9	93.0	64.0	6.1	0.0	2.4	0.27	0.93	0.83	0.23	0.03	0.46
77	Suriname	16.5	22.8	18.5	94.0	77.0	25.2	0.0	4.2	0.25	0.82	0.88	0.28	0.05	0.46
78	South Africa	9.5	30.4	15.4	85.6	78.0	12.4	0.0	6.8	0.23	0.85	0.83	0.26	0.08	0.45
79	Colombia	17.4	10.6	12.2	91.9	71.0	12.7	0.1	4.6	0.20	0.88	0.85	0.26	0.05	0.45
80	Jordan	12.7	22.9	18.0	90.3	77.0	16.9	0.0	5.8	0.22	0.82	0.86	0.27	0.07	0.45
81	Serbia & Montenegro	23.1	25.7	11.3	91.7	52.0	0.9	0.0	6.0	0.32	0.89	0.78	0.16	0.07	0.45
82	Saudi Arabia	14.4	21.7	4.9	77.1	58.0	12.9	0.0	6.2	0.23	0.95	0.71	0.26	0.07	0.44
83	Peru	7.6	8.6	19.2	90.2	83.0	45.6	0.1	9.3	0.11	0.81	0.88	0.31	0.11	0.44
84	China	16.7	16.1	12.9	85.8	64.0	7.3	0.2	4.6	0.22	0.87	0.79	0.24	0.05	0.43
85	Fiji	11.7	10.8	17.6	93.2	76.0	9.6	0.0	6.0	0.15	0.82	0.87	0.25	0.07	0.43
86	Botswana	8.3	24.1	10.9	78.1	80.0	15.1	0.0	2.9	0.19	0.89	0.79	0.26	0.03	0.43
87	Iran (I.R.)	18.7	3.3	4.2	77.1	64.0	8.4	0.0	4.8	0.17	0.96	0.73	0.24	0.06	0.43
88	Ukraine	21.6	8.4	26.0	99.6	81.0	6.3	0.0	1.8	0.22	0.74	0.93	0.23	0.02	0.43
89	Guyana	9.2	9.9	29.8	98.6	84.0	3.5	0.0	14.2	0.13	0.70	0.94	0.21	0.17	0.43
90	Philippines	4.2	19.4	20.1	95.1	80.0	11.2	0.1	4.4	0.13	0.80	0.90	0.26	0.05	0.43
91	Oman	8.4	17.1	3.8	73.0	58.0	14.0	0.0	6.6	0.16	0.96	0.68	0.26	0.08	0.43
92	Maldives	10.2	14.9	29.6	97.0	79.0	32.0	0.1	5.3	0.16	0.70	0.91	0.29	0.06	0.43
93	Libya	11.9	1.3	3.8	80.8	89.0	1.1	0.0	2.3	0.11	0.96	0.84	0.17	0.03	0.42
94	Dominican Rep.	10.4	19.5	17.1	84.0	74.0	5.9	0.0	3.4	0.18	0.83	0.81	0.23	0.04	0.42
95	Tunisia	11.7	5.1	10.4	72.1	76.0	7.6	0.0	5.2	0.12	0.90	0.73	0.24	0.06	0.41
96	Ecuador	11.4	12.6	26.3	91.8	72.0	6.1	0.1	4.3	0.16	0.74	0.85	0.23	0.05	0.41
97	Kazakhstan	13.0	6.4	27.4	99.4	78.0	4.3	0.0	1.6	0.14	0.73	0.92	0.22	0.02	0.41
98	Egypt	11.5	6.7	4.5	56.1	76.0	10.9	0.0	2.8	0.13	0.96	0.63	0.25	0.03	0.40
99	Cape Verde	15.6	9.5	28.4	74.9	80.0	17.8	0.0	3.6	0.18	0.72	0.77	0.27	0.04	0.39
100	Albania	7.1	25.9	24.8	85.3	69.0	3.9	0.0	0.4	0.19	0.75	0.80	0.22	0.00	0.39
101	Paraguay	4.7	28.8	37.3	93.5	64.0	17.3	0.0	1.7	0.18	0.63	0.84	0.27	0.02	0.39
102	Namibia	6.5	10.7	22.5	82.7	74.0	4.5	0.0	2.7	0.11	0.77	0.80	0.22	0.03	0.39
103	Guatemala	7.1	13.1	21.4	69.2	57.0	72.9	0.0	3.3	0.12	0.79	0.65	0.32	0.04	0.38
104	El Salvador	10.3	13.8	27.8	79.2	64.0	6.7	0.0	4.6	0.15	0.72	0.74	0.24	0.05	0.38
105	Palestine	8.7	9.3	32.8	89.2	77.0	5.8	0.0	3.0	0.12	0.67	0.85	0.23	0.04	0.38
106	Sri Lanka	4.7	4.9	21.5	91.9	63.0	4.8	0.0	1.1	0.06	0.79	0.82	0.22	0.01	0.38
107	Bolivia	6.8	10.5	29.8	86.0	84.0	2.2	0.0	3.2	0.11	0.70	0.85	0.19	0.04	0.38
108	Cuba	5.1	0.2	29.8	96.8	76.0	4.6	0.0	1.1	0.04	0.70	0.90	0.22	0.01	0.38
109	Samoa	5.7	1.5	36.3	98.7	71.0	11.1	0.0	2.2	0.06	0.64	0.89	0.25	0.03	0.37
110	Algeria	6.1	1.3	12.4	67.8	71.0	5.0	0.0	1.6	0.06	0.88	0.69	0.22	0.02	0.37
111	Turkmenistan	7.7	0.2	20.0	98.0	81.0	0.1	0.0	0.2	0.07	0.80	0.92	0.06	0.00	0.37
112	Georgia	13.1	10.2	46.4	100.0	69.0	6.1	0.0	1.5	0.16	0.54	0.90	0.23	0.02	0.37
113	Swaziland	3.3	6.1	21.0	80.3	77.0	1.0	0.0	1.9	0.06	0.79	0.79	0.17	0.02	0.37
114	Moldova	17.0	7.7	49.6	99.0	61.0	7.7	0.0	3.4	0.18	0.50	0.86	0.24	0.04	0.37
115	Mongolia	5.3	8.9	48.6	98.5	64.0	7.0	0.0	2.1	0.09	0.51	0.87	0.24	0.02	0.35
116	Indonesia	3.7	5.5	37.6	87.3	64.0	2.7	0.0	3.8	0.06	0.62	0.80	0.20	0.04	0.34
117	Gabon	2.5	21.6	46.9	71.0	83.0	12.6	0.0	1.9	0.13	0.53	0.75	0.26	0.02	0.34
118	Morocco	3.8	20.9	25.5	49.8	51.0	10.5	0.0	2.4	0.14	0.74	0.50	0.25	0.03	0.33
119	India	4.0	1.2	21.9	58.0	56.0	1.6	0.0	1.6	0.04	0.78	0.57	0.18	0.02	0.32
120	Kyrgyzstan	7.9	1.1	54.0	97.0	79.0	0.2	0.0	3.0	0.07	0.46	0.91	0.10	0.04	0.32
121	Uzbekistan	6.6	0.7	53.8	99.2	76.0	0.2	0.0	1.1	0.06	0.46	0.91	0.11	0.01	0.31
122	Viet Nam	4.8	2.3	55.4	92.7	64.0	1.8	0.0	1.8	0.05	0.45	0.83	0.19	0.02	0.31
123	Armenia	14.3	1.9	68.0	98.5	60.0	2.1	0.0	1.6	0.13	0.32	0.86	0.19	0.02	0.30

		Sub lines p. 100 inhab.	Mobile sub. p. 100 inhab.	Internet tariff as % of GNI	Adult Liter-acy	School enroll-ment	Int'l Internet bandwidth p. 100 inhab.	Broad band subscribers p. 100 inhab.	Internet users p. 100 inhab.	INFRA-STRUCTURE	AFFORD-ABILITY	KNOW-LEDGE	QUALITY	USAGE	DAI
	LOW														
124	Zimbabwe	2.5	3.0	58.3	89.3	59.0	0.9	0.0	4.3	0.04	0.42	0.79	0.16	0.05	0.29
125	Honduras	4.8	4.9	52.9	75.6	62.0	1.5	0.0	2.5	0.06	0.47	0.71	0.18	0.03	0.29
126	Syria	12.3	2.3	58.6	75.3	59.0	0.9	0.0	1.3	0.11	0.41	0.70	0.16	0.02	0.28
127	Papua New Guinea	1.1	0.2	45.3	64.6	41.0	1.1	0.0	1.4	0.01	0.55	0.57	0.17	0.02	0.26
128	Vanuatu	3.2	2.4	51.9	34.0	54.0	9.8	0.0	3.4	0.04	0.48	0.41	0.25	0.04	0.24
129	Pakistan	2.5	0.8	45.7	44.0	36.0	2.8	0.0	1.0	0.03	0.54	0.41	0.20	0.01	0.24
130	Azerbaijan	12.2	10.7	183.0	97.0	69.0	0.3	0.0	3.7	0.15	0.00	0.88	0.12	0.04	0.24
131	S. Tomé & Principe	4.1	1.3	287.7	83.1	58.0	13.2	0.0	7.3	0.04	0.00	0.75	0.26	0.09	0.23
132	Tajikistan	3.7	0.2	362.3	99.3	71.0	0.3	0.0	0.1	0.03	0.00	0.90	0.12	0.00	0.21
133	Equatorial Guinea	1.8	6.4	177.1	84.2	58.0	2.0	0.0	0.4	0.05	0.00	0.75	0.19	0.00	0.20
134	Kenya	1.0	4.2	152.4	83.3	52.0	1.8	0.0	1.3	0.03	0.00	0.73	0.19	0.01	0.19
135	Nicaragua	3.2	3.8	138.6	66.8	65.0	6.0	0.0	1.7	0.05	0.00	0.66	0.23	0.02	0.19
136	Lesotho	1.6	4.2	110.7	83.9	63.0	0.5	0.0	1.0	0.03	0.00	0.77	0.14	0.01	0.19
137	Nepal	1.4	0.1	70.3	42.9	64.0	0.4	0.0	0.3	0.01	0.30	0.50	0.14	0.00	0.19
138	Bangladesh	0.5	0.8	66.8	40.6	54.0	0.3	0.0	0.2	0.01	0.33	0.45	0.12	0.00	0.18
139	Yemen	2.8	2.1	75.3	47.7	52.0	0.3	0.0	0.5	0.03	0.25	0.49	0.12	0.01	0.18
140	Togo	1.1	3.6	134.9	58.4	67.0	2.6	0.0	4.3	0.03	0.00	0.61	0.20	0.05	0.18
141	Solomon Islands	1.5	0.2	191.9	76.6	50.0	1.2	0.1	0.5	0.01	0.00	0.68	0.17	0.01	0.17
142	Cambodia	0.3	2.8	212.8	68.7	55.0	1.5	0.0	0.2	0.02	0.00	0.64	0.18	0.00	0.17
143	Uganda	0.2	2.0	464.4	68.0	71.0	0.4	0.0	0.4	0.01	0.00	0.69	0.13	0.00	0.17
144	Zambia	0.8	1.3	118.7	79.0	45.0	0.5	0.0	0.5	0.01	0.00	0.68	0.14	0.01	0.17
145	Myanmar	0.7	0.1	180.9	85.0	47.0	0.2	0.0	0.1	0.01	0.00	0.72	0.11	0.00	0.17
146	Congo	0.7	6.7	207.8	81.8	57.0	0.0	0.0	0.2	0.04	0.00	0.74	0.05	0.00	0.17
147	Cameroon	0.7	4.3	110.7	72.4	48.0	0.6	0.0	0.4	0.03	0.00	0.64	0.15	0.00	0.16
148	Ghana	1.3	2.4	177.8	72.7	46.0	0.6	0.0	0.8	0.02	0.00	0.64	0.15	0.01	0.16
149	Lao P.D.R.	1.1	1.0	123.4	65.6	57.0	0.3	0.0	0.3	0.01	0.00	0.63	0.12	0.00	0.15
150	Malawi	0.7	0.8	465.0	61.0	72.0	0.2	0.0	0.3	0.01	0.00	0.65	0.11	0.00	0.15
151	Tanzania	0.5	1.9	501.4	76.0	31.0	0.5	0.0	0.2	0.01	0.00	0.61	0.14	0.00	0.15
152	Haiti	1.6	1.7	354.5	50.8	52.0	4.2	0.0	1.0	0.02	0.00	0.51	0.22	0.01	0.15
153	Nigeria	0.6	1.3	353.7	65.4	45.0	0.6	0.0	0.3	0.01	0.00	0.59	0.15	0.00	0.15
154	Djibouti	1.5	2.3	153.2	65.5	21.0	3.1	0.0	0.7	0.02	0.00	0.51	0.21	0.01	0.15
155	Rwanda	0.3	1.4	348.3	68.0	52.0	0.2	0.0	0.3	0.01	0.00	0.63	0.10	0.00	0.15
156	Madagascar	0.4	1.0	336.7	67.3	41.0	0.4	0.0	0.3	0.01	0.00	0.59	0.13	0.00	0.15
157	Mauritania	1.2	9.2	113.1	40.7	43.0	3.5	0.0	0.4	0.06	0.00	0.41	0.21	0.00	0.14
158	Senegal	2.3	5.6	103.7	38.3	38.0	8.1	0.0	1.1	0.05	0.00	0.38	0.24	0.01	0.14
159	Gambia	2.8	7.3	116.2	37.8	47.0	1.5	0.0	1.8	0.06	0.00	0.41	0.18	0.02	0.13
160	Bhutan	2.8	0.0	148.5	47.0	33.0	2.9	0.0	1.4	0.02	0.00	0.42	0.21	0.02	0.13
161	Sudan	2.1	0.6	550.8	58.8	34.0	0.3	0.0	0.3	0.02	0.00	0.51	0.12	0.00	0.13
162	Comoros	1.4	0.0	206.0	56.0	40.0	0.3	0.0	0.4	0.01	0.00	0.51	0.13	0.00	0.13
163	Côte d,Ivoire	2.0	6.2	132.1	49.7	39.0	0.4	0.0	0.5	0.05	0.00	0.46	0.13	0.01	0.13
164	Eritrea	0.9	0.0	200.9	56.7	33.0	0.5	0.0	0.2	0.01	0.00	0.49	0.14	0.00	0.13
165	D.R. Congo	0.0	1.1	986.7	62.7	27.0	0.2	0.0	0.1	0.01	0.00	0.51	0.11	0.00	0.12
166	Benin	1.0	3.3	146.5	38.6	49.0	0.3	0.0	0.8	0.02	0.00	0.42	0.13	0.01	0.12
167	Mozambique	0.5	1.4	233.1	45.2	37.0	0.5	0.0	0.2	0.01	0.00	0.42	0.14	0.00	0.12
168	Angola	0.6	0.9	143.3	42.0	29.0	0.5	0.0	0.3	0.01	0.00	0.38	0.14	0.00	0.11
169	Burundi	0.3	0.7	703.2	49.2	31.0	0.1	0.0	0.1	0.01	0.00	0.43	0.08	0.00	0.10
170	Guinea	0.3	1.2	185.2	41.0	34.0	0.2	0.0	0.5	0.01	0.00	0.39	0.11	0.01	0.10
171	Sierra Leone	0.5	1.3	857.1	36.0	51.0	0.1	0.0	0.2	0.01	0.00	0.41	0.08	0.00	0.10
172	Central African Rep.	0.2	0.3	807.9	48.2	24.0	0.1	0.0	0.1	0.00	0.00	0.40	0.09	0.00	0.10
173	Ethiopia	0.5	0.1	329.0	40.3	34.0	0.1	0.0	0.1	0.00	0.00	0.38	0.10	0.00	0.10
174	Guinea-Bissau	0.9	0.0	840.0	39.6	43.0	0.1	0.0	0.4	0.01	0.00	0.41	0.06	0.00	0.10
175	Chad	0.2	0.4	375.7	44.2	33.0	0.1	0.0	0.2	0.00	0.00	0.40	0.07	0.00	0.10
176	Mali	0.5	0.5	289.8	26.4	29.0	0.6	0.0	0.2	0.01	0.00	0.27	0.15	0.00	0.09
177	Burkina Faso	0.5	0.8	247.5	24.8	22.0	0.7	0.0	0.2	0.01	0.00	0.24	0.15	0.00	0.08
178	Niger	0.2	0.1	683.6	16.5	17.0	0.0	0.0	0.1	0.00	0.00	0.17	0.05	0.00	0.04

Source: ITU (2003): World Telecommunication Development Report 2003, Table 5.4
[Reproduced with the kind permission of ITU]

The Report discusses how raw numbers are translated into scores that are weighted for the overall DAI score.

Appendix 3: Washington, D.C., Workshop Details

Agenda – Washington Workshop on IT and Sustainable Development

June 26-27, 2003

	June 26th	(Day 1)
First Session Chair: Dr. Gary Strong (DHS)	8:30-9:00 am:	*Continental breakfast*
	9:00-9:15 am:	Setting the Stage – Prof. Raj Reddy, Carnegie Mellon University
	9:15-9:30 am:	Keynote Address by Dr. Rita Colwell, Director, NSF
	9:30-9:45 am:	Plenary Address by Ms. Jocelyne Albert, The World Bank
	9:45-10:15 am:	Inaugural Address – Mr. Nitin Desai, Under-Secretary General, UN
Second Session Chair: Prof. Richard Newton (UC-Berkeley)	10:15-10:35 am:	Development and Deprivation – Prof. V. S. Arunachalam, Carnegie Mellon University
	10:35-10:55 am:	Discussion
	10:55-11:25 am:	*Refreshment Break*
	11:25-11:45 am:	Agriculture, Land-use, and Sustainability – Prof. Rattan Lal, Ohio State University
	11:45-12:05 am:	Discussion
	12:05-1:20 pm:	*Lunch*
	1:20-1:40 pm:	Drinking water and sanitation – Prof. Peter Rogers, Harvard University
	1:40- 2:00 pm:	Discussion
	2:00-2:20 pm:	Human health and development – Prof. W. Henry Mosley, Johns Hopkins University
	2:20-2:40 pm:	Discussion
	2:40-3:10 pm:	*Refreshment Break*
Third Session Chair: Dr. Carlos Braga (World Bank)	3:10-3:30 pm:	Development and e-development – Dr. Nagy Hanna, The World Bank
	3:30-3:50 pm:	Discussion
	3:50-4:10 pm:	Economic growth in developing countries – Prof. T. N. Srinivasan, Yale University
	4:10-4:30 pm:	Discussion
	4:30-4:50 pm:	Is research relevant to developing countries? – Dr. David Jhirad, World Resources Institute
	4:50-5:10 pm:	Discussion
	5:10-6:00 pm:	*Break, head to Wyndham City Center Hotel, New Hampshire Avenue*
	6:00 pm onwards:	*Reception and Dinner – Wyndham City Center – Potomac Room*

	June 27th	(Day 2)
	8:30-9:00 am:	*Continental Breakfast*
Fourth Session Chair: Prof. Eric Brewer (UC-Berkeley)	9:00-9:20 am:	IT, the World Bank, and Development – Dr. Carlos A. Braga, The World Bank
	9:20-9:40 am:	Discussion
	9:40-10:00 am:	Transportation and Urban Planning – Dr. Nancy Kete, World Resources Institute/EMBARQ
	10:00-10:20 am:	Discussion
	10:20-10:50 am:	*Refreshment Break*
	10:50-11:10 am:	Energy and Electricity Issues in developing countries – Dr. David Victor, Stanford University
	11:10-11:30 am:	Discussion
	11:30-11:50 am:	Relationship between IT and Sustainable Development – Mr. Tom Kalil, UC-Berkeley
	11:50-12:10 pm:	Discussion
	12:10-1:10 pm:	*Lunch* *Talk by Mohamed Muhsin, World Bank, "The World Bank, IT, and Sustainable Development"*
Fifth Session Chair: Prof. T.N. Srinivasan (Yale University)	1:10-2:10 pm:	Observations from the frontlines – International Participants
	2:10-2:30 pm:	Discussion
	2:30-3:00 pm:	Summing up
		Setting the theme for the Next Stage of the IT for Sustainability Workshop

Washington, D.C. Workshop Select Highlights

Opening Session (L to R):
Rita Colwell (NSF),
Nitin Desai (UN), and
V. S. Arunachalam (CMU)

Making a Statement: Carlos Braga (World Bank)

Developing Countries Perspectives Discussion (L to R):
Walter Alhassan (Ghana),
Chrissie Mwiyeriwa (Malawi),
T. N. Srinivasan (Yale Univ.),
Dirk Pilari (UN), and
Ambika Sharma (India)

Participants – Washington Workshop on IT and Sustainable Development

June 26-27, 2003

Jocelyne Albert
Senior Regional Coordinator
World Bank
USA

Walter Alhassan
Director-General (retd.)
CSIR Secretariat
Ghana

V. S. Arunachalam
Professor
Dept. of Engineering & Public Policy/Materials Science & Engineering/Robotics Inst. (School of Computer Science)
Carnegie Mellon
USA

N. Balakrishnan
Professor
Indian Institute of Science/Carnegie Mellon
India

Anshu Bharadwaj
Research Fellow
Dept. of Engineering & Public Policy
Carnegie Mellon
USA

R. Bhaskar
Professor
Harvard Business School
USA

Carlos Braga
Senior Manager
Informatics Program
World Bank
USA

Eric Brewer
Professor
UC-Berkeley
USA

Moira Burns
National Science Foundation
USA

Liz Casman
Research Engineer
Carnegie Mellon
USA

Fernando Chaparro
Executive Director
Columbian Digital Corporation
Columbia

Vivek Chaudhry
Program Administrator
World Bank
USA

Rita Colwell
Director
National Science Foundation
USA

Anita Connelly
Administrator
Carnegie Mellon
USA

Ruth Connolly
Organization of American States
USA

Anthony Cresswell
Professor
SUNY-Albany
USA

Khadisha Dairova
Embassy of Kazakhstan
Kazakhasthan

Cliff Davidson
Professor
Carnegie Mellon
USA

Nitin Desai
Under-Secretary General (Economic and Social Affairs)
United Nations
USA

M. Bernardine Dias
Researcher
Carnegie Mellon
Sri Lanka

Nafeeza Fazal
Minister of State for Science & Technology
Dept. of Science & Technology
Govt. of Karnataka, India
India

Patrice Flynn
President
Flynn Research
USA

Ed Fredkin
Professor
Carnegie Mellon
USA

Valerie Gregg
Program Manager
Digital Government Research Program
National Science Foundation
USA

Nagy Hanna
Senior Advisor, e-Development
World Bank
USA

Miriam Heller
Program Manager
Engineering Directorate
National Science Foundation
USA

David Jhirad
Vice-President
VP-Research
World Resources Institute
USA

Dan Johnson
National Science Foundation
USA

Tom Kalil
Special Assistant to the Chancellor for Science & Technology
UC-Berkeley
USA

Nancy Kete
Senior Fellow
World Resources Institute/EMBARQ
USA

Robin King
Professor
Communications, Culture, and Technology
Georgetown University
USA

Pat Koshel
Senior Program Officer
National Academy of Sciences
USA

Rattan Lal
Professor
Ohio State University
USA

Richard Lempert
Division Director
Social and Economic Sciences
National Science Foundation
USA

Stephen Meacham
National Science Foundation
USA

Mari Maeda
Program Director
CISE
National Science Foundation
USA

Kui-Nang Mak
Chief
Energy & Transport Branch
United Nations
USA

Sujata Millick
Technology Policy Analyst
Office of Technology Policy
US Dept. of Commerce
USA

Henry Mosley
Professor
Bloomberg School of Public Health
Johns Hopkins University
USA

Mohamed Muhsin
Vice-President and CIO
World Bank
USA

Chrissie Mwiyeriwa
Secretary
National Research Council of Malawi
Malawi

Richard Newton
Dean
College of Engineering
UC-Berkeley
USA

Leisa Perch
Organization of American States
USA

Dirk Pilari
Senior Economic Affairs Officer
United Nations
USA

Ramji Raghavan
Chairman
Agastya Foundation
India

Raj Reddy
Professor
School of Computer Science
Carnegie Mellon
USA

Peter Rogers
Professor
Harvard University
USA

Ambuj Sagar
Fellow
Harvard University
USA

Roald Sagdev
Professor
University of Maryland
USA

Bill Scherlis
Principal Research Scientist
Carnegie Mellon
USA

Michael Shamos
Professor
Carnegie Mellon
USA

Ambika Sharma
Program Officer
Development Alternatives
India

Mel Siegel
Senior Research Scientist
Robotics Institute
Carnegie Mellon
USA

William Sonntag
Chief of Staff
CIO's Ofice
EPA
USA

T. N. Srinivasan
Professor
Yale University
USA

Sue Stendebach
Program Manager
Digital Government Research Program
National Science Foundation
USA

Jan Stout
National Science Foundation
USA

Gary Strong
Director
Behavioral Research, S&T Directorate
US Dept. of Homeland Security
USA

Stanley Su
Distinguished Professor & Director
Database Systems R&D Center
University of Florida
USA

Eswaran Subrahmanian
Senior Research Faculty
Institute for Complex Engineered Systems
Carnegie Mellon
USA

Frederick Tipson
Executive Director
Global Digital Opportunity Initiative
Markle Foundation
USA

Rahul Tongia
Systems Scientist
ISRI-School of Computer Science/Dept. of Engineering & Public Policy
Carnegie Mellon
USA

Kung Tun
Chief
Project Review Office
Ministry of Environment, Cambodia
Cambodia

Shalini Vajjhala
Graduate Research Assistant
Carnegie Mellon
USA

David Victor
Director
Program on Energy and Sustainable Development
Stanford University
USA

Peter Wiesner
Manager
Business Development, Educational Activities
IEEE
USA

Juwang Zhu
Sustainable Development Officer
United Nations
USA

While all attempts have been made in the list above, we cannot guarantee its accuracy or completeness.

Appendix 4: Bangalore Workshop Details

Agenda – Bangalore Workshop on IT and Sustainable Development

January 14-16, 2004

	January 14, 2004	**(Day 1)**
Plenary Session	10:00-10:30 am:	*Registration and Tea*
	10:30-10:45 am:	Welcome Remarks – Prof. N. Balakrishnan, IISc. Opening Remarks – Ms. JoAnne DiSano, UN; Dr. Carlos Braga, World Bank; and Dr. Peter Freeman, NSF
	10:45-11:00 am:	ICT for SD: A resume – Prof. V. S. Arunachalam, CMU
Chair: (1) Dr. A. Ramachandran (UN, retd.) (2) Mr. K.K. Jaswal (MCIT, India)	11:00-12:20 am:	Keynote Address on WSIS and ICT: (1) Mr. Nitin Desai, UN (retd.) (2) Prof. Richard Newton, UC-Berkeley
	12:20-12:35 pm:	Developing Country Needs and Perspectives in ICT – Prof. Susana Finquelievich, University of Buenos Aires
	12:35-2:00 pm:	*Lunch*
	2:00-5:30 pm:	Working Groups
	7:30-9:30 pm:	*Dinner*
	January 15, 2005	**(Day 2)**
		Plan of Action/Announcements
Chair: Dr. Carlos Braga (World Bank)	9:30-10:10 am:	Keynote Address on Development and Economics Prof. Joseph Stiglitz, Columbia University
	10:10-12:30 pm:	Working Groups
	12:30-1:30 pm:	*Lunch*
	1:30-2:00 pm:	Development and Security – Dr. Ronald Lehman, Lawrence Livermore Natl. Lab
	2:00-2:15 pm:	ICT & Development: Who Pays, How Much? – Prof. Raj Reddy, CMU
Chair: Ms. JoAnne DiSano (UN) Co-Chairs: Dr. S. Varadarajan (INSA), Prof. Bill Scherlis (CMU)	2:15-5:15 pm:	Presentations by Working Groups and Joint Discussions
	7:30-9:30 pm:	*Dinner*

	January 16, 2004	(Day 3)
Valedictory Session	9:30-10:45 am:	Remarks by – (Late) Dr. Raja Ramanna, NIAS; Ms. JoAnne Disano, UN; Dr. Carlos Braga, World Bank; Dr. Peter Freeman, NSF; Prof. Raj Reddy, CMU; and Prof. V. S. Arunachalam, CMU Address by H.E. Dr. A.P.J. Abdul Kalam, President of India Vote of Thanks – Prof. N. Balakrishnan, IISc
	10:45-11:15 am:	*Tea with the President of India*
	11:15-12:00 pm:	Research Agenda Prioritization and Discussions Tom Kalil, UC-Berkeley
	12:00-12:45 pm:	Linkages, Partnerships, and Mechanisms for Implementation Dr. Kui-Nang Mak, UN
	12:45-1:00 pm:	Where Do We Go From Here? – Dr. V. S. Arunachalam, CMU
	1:00-1:15 pm:	Closing Remarks – Dr. Peter Freeman, NSF
	1:15 pm	*Workshop Concludes; Lunch*
	January 17, 2004	**(Day 4)**
		(Optional) Industry/Site Visits

Bangalore Workshop Select Highlights

Inaugural Session (L to R): Carlos Braga (World Bank), V. S. Arunachalam (CMU), Peter Freeman (NSF), JoAnne DiSano (UN), A. Ramachandran (NIAS), Raj Reddy (CMU)

Keynote Address: Joseph Stiglitz (Columbia Univ.) being introduced by Carlos Braga (World Bank)

Breakout Group Sessions: Working Group on Human Development

Valedictory Session (L to R podium and onstage): (late) Raja Ramanna (NIAS), Carlos Braga (WorldBank), Peter Freeman (NSF), JoAnne DiSano (UN), Raj Reddy (CMU), H.E. President APJ Abdul Kalam, H.E. Governor T. N. Chaturvedi, V. S. Arunachalam (CMU), N. Balakrishnan (IISc)

Participants – Bangalore Workshop on IT and Sustainable Development

January 14-16, 2004

V. K. Aatre
Secretary
DRDO
Govt. of India
India

Talal Aboud
Scientific Studies and Research Centre
Syria

Dulcy Abraham
Assoc. Professor
Civil Engineering
Purdue
USA

Bruce Alberts
President
National Academy of Sciences
USA

Yahya M. Al-Sharafi
National Water Resources Authority
Yemen

P. Anandan
Microsoft
India

James Arputharaj
Executive Director
South Asia Partnership International
Sri Lanka

V. S. Arunachalam
Professor
Engineering & Public Policy/School of Computer Science/Materials Science & Engineering
Carnegie Mellon
USA

V. Balaji
Head
Information Resource Management
ICRISAT
India

N. Balakrishnan
Chairman
Information Sciences
Indian Inst. Of Science
India

Vivek Balaraman
Scientist
Research Dev. & Design Center
Tata Consultancy Services
India
Hoda Baraka
National Project Director (MCIT)
Ministry of Communications and IT
Egypt

Yashwant Bhave
Joint-Secretary
Ministry of Communications and Information Technology
India

Carlos Braga
Senior Advisor
Intl. Trade
World Bank
Switzerland

Lawrence Brandt
Program Manager
CISE
National Science Foundation
USA

Eric Brewer
Assoc. Professor
EECS
University of California, Berkeley
USA

Rudolfo Castillo-Lopez
Director
Agency for the Development of the Inform. Soc. of Bolivia
Bolivia

R Chandrashekhar
Joint Secretary
e-Governance
MCIT
India

Vijay Chandru
Professor
Comp. Sc. & Automation
Indian Inst. Of Science
India

Fernando Chaparro
Director
Digital Columbia
Columbia

T. N. Chaturvedi
H. E. Governor of Karnataka
India

Tony Crewsswell
Associate Professor
SUNY-Albany
USA

Joseph Davis
Professor
Computer Science
Univ. of Sydney
Australia

Nitin Desai
Under-Secretary General (retd.)
United Nations
USA

Parag Deshpande
Coordinator
Software/User Interface Design
National Institute of Design
India

M. Bernardine Dias
Special Faculty
School of Computer Science
Carnegie Mellon
USA

JoAnne DiSano
Director
Division For Sustainable Development
United Nations
USA

Kunzang Dorji
Deputy Director
Information Communication and Outreach Section
National Environment Commission
Bhutan

Rupa Sriyani Eknayake
Director
Human Resources Department
Ministry of Environment & Natural Resources
Sri Lanka

Kevin Fall
Fellow
Intel
USA

Susana Finquelievich
Director
Research Program on Information Society
University of Buenos Aires
Argentina

Jose Fortes
Professor
U. of Florida
USA

Peter Freeman
Asst. Director for CISE
National Science Foundation
USA

Stuart Gannes
Director
Digital Vision Fellowship
Stanford
USA

Atma Ram Ghimire
Nat. Information Technology Centre
Nepal

S Ghosal
Head
Bangalore Centre
National Institute of Design
India

Gita Gopal
Asst. Director
HP Labs India
USA

Valerie Gregg
Program Manager
CISE
National Science Foundation
USA

J. Gururaja
Advisor
United Nations
USA

K. N. Hari Kumar
Managing Director
e-tapaal
India

Vishaka Hidellage
Country Director
ITDG South Asia
Sri Lanka

Keiichi Ishihara
Professor
Kyoto University
Japan

Ashok Jain
Delhi University
India

A P J Abdul Kalam
H.E. The President of India

Tom Kalil
Special Assistant to the Chancellor for Science and Technology
University of California, Berkeley
USA

Ken Keniston
Professor
MIT
USA

P. C. Kesavan
Professor
M.S.Swaminathan Res.Foundation
India

Ashok Khosla
President
Development Alternatives
India

Beth Kolko
Assoc. Professor
Department of Technical Communication
U. of Washington
USA

Darlie O. Koshy
Director
National Institute of Design
India

Gopi Krishna
India

M Krishnamurthi
Trustee
M. Venkatarangiyah Foundation
India

Alfonso Lafuente
President
National Center for IT (CNTI)
Venezuela

Sunil Lal
Senior Research Scientist
Intl. Ctre for Gen. Engg. & Tech.
India

Emmanuel C Lallana
Executive Director
e-ASEAN Task Force
Philippines

Ronald Lehman
Director
Center for Global Security Research
Lawrence Livermore Natl. Lab
USA

Richard Lempert
National Science Foundation
USA

Kui-Nang Mak
Chief
Energy and Transport Branch
United Nations
USA

Swamy Manohar
Professor
Comp. Sc. & Automation
Indian Inst. of Science
India

Ramona Miranda
ITDG South Asia
Sri Lanka

M. D. Mohsin
Senior Assistant Secretary
Ministry of Environment & Forests
Bangladesh

Benoit Morel
Professor
Dept. of Engineering & Public Policy
Carnegie Mellon
USA

M. Granger Morgan
Professor
Carnegie Mellon
USA

Nandan Nilekani
CEO
Infosys
India

M. K. Narayanan
Director (retd.)
Intelligence Bureau
India

Ravi Narayanan
Director
WaterAid
UK

Ramamurthy Natarajan
Chairman
AICTE
India

Indira Nath
Professor
AIIMS, New Delhi
India

Abdoulaye Ndiaye
Technical Adviser on IT to the Prime Minister
Govt. of Senegal
Senegal

Richard Newton
Dean
University of California, Berkeley
USA

Zerubabel M. Nyiiria
Executive Secretary and National ACACIA Programme Coordinator
Uganda National Council for Science and Technology
Uganda

John Onyatta
Principal Research Officer
Department of Research Development
Kenya

Joyojeet Pal
Researcher
University of California, Berkeley
USA

D. B. Pathak
Professor & Head
KReSIT
IIT, Mumbai
India

Rabin Patra
Researcher
University of California, Berkeley
USA

Anand Patwardhan
Professor and Head
S J Mehta School of Management
IIT, Mumbai
India

Feniosky Peña-Mora
Assoc. Professor
U. of Illinois, Urbana-Champaign
USA

Vishweshwaraiah Prakash
Director
CFTRI
India

Bui Duc Quang
Head of Group for Computer and Electronics Industries
Department of Information Technology Industry
Ministry of Posts and Telematics
Vietnam

Ramji Raghavan
Chairman
Agastya Foundation
India

Hakikur Rahman
Project Coordinator
Sustainable Development Networking Programme (SDNP)
Bangladesh

Y. S. Rajan
Vice Chancellor
Punjab Technical University
India

A. Ramachandran
Chairman
The Energy Research Institute (TERI)
India

A. Ramakrishna
President (Op.) & Dy MD
Larsen & Toubro Ltd.
India

Krithi Ramamritham
Professor
Comp. Sc. & Engg.
IIT, Mumbai
India

Bhaskaran Raman
Asst. Professor
Comp. Sc. & Engg.
IIT, Kanpur
India

Late Raja Ramanna
Director (Emeritus)
National Institute of Advanced Studies
India

Raj Reddy
Professor
School of Computer Science
Carnegie Mellon
USA

Justus Roux
Professor
University of Stellenbosch
South Africa

Roald Sagdev
Professor
U. of Maryland
USA

Varun Sahni
Project Shakti
Hindustan Lever Ltd
India

Walt Schearer
Business Manager
ISRI, School of Computer Science
Carnegie Mellon
USA

Bill Scherlis
Principal Research Scientist
School of Computer Science
Carnegie Mellon
USA

Angus Scrimgeour
Scrimgeour Inc.
USA/India

Michael Shamos
Director, e-Commerce Inst.
School of Computer Science
Carnegie Mellon
USA

R. K. Shukla
Principal Statistician
Sample Survey and Gen. Econ.
NCAER, India

Mel Siegel
Assoc. Research Professor
School of Computer Science
Carnegie Mellon
USA

Shanta Sinha
Professor
Political Science
University of Hyderabad
India

Friedrich Soltau
Sustainable Development Officer
United Nations
USA

Kong Kim Sreng
Technical Officer
Department of Nature Conservation
Ministry of Environment
Cambodia

Uma Srinivasan
Research Group Leader
Health Data Integration
CSIRO
Australia

Srinivasan Ramani
Director
HP Labs India
India

Joseph Stiglitz
Professor
Columbia University
USA

Eswaran Subrahmanian
Research Professor
Carnegie Mellon/NIST
USA

P. V. Subrahmanyam
Member
Byrraju Foundation
India

Aruna Sunderarajan
Secretary, IT
Govt of Kerala
India

Subrahmanian Suresh
Professor
MIT
USA

Ngurah Swajaya
Senior Expert on Economic and Environmental Affairs
Dept. of Foreign Affairs
Indonesia

William Thompson
State Representative
UNICEF
India

Rahul Tongia
Systems Scientist
School of Computer Science/Engineering & Public Policy
Carnegie Mellon
USA

Srinivasan Varadarajan
Past President
Indian National Science Academy
India

K. I. Vasu
National President
Vijnana Bharati
India

David Victor
Director
Program on Energy and Sustainable Development
Stanford
USA

T. Vijay Kumar
CEO
Velugu Project
India

Ernest Wilson
Professor
U. of Maryland
USA

David Zoellner
Nexant
Philippines

Xiang Fu Zong
Founding President and Professor
Shanghai Int. Institute of Information Science & Tech
China

While all attempts have been made in the list above, we cannot guarantee its accuracy or completeness

Appendix 5: Bangalore Workshop Questionnaires

Questionnaires were distributed to workshop participants and other select professionals in advance of the Bangalore Workshop to aid in structuring discussions and creating a Discussion Note (which was also circulated in advance of the Workshop). Dozens of responses were received, and these helped form many of the thematic group challenges and barriers presented in the Thematic Groups chapter of the Report.

Questionnaire for Infrastructure and Human Development
(Energy, Water & Sanitation, Transportation, Education, Healthcare)

Note: The workshop website (http://www.cs.cmu.edu/~rtongia/itsd.htm) gives information on the Workshop agenda and on ICT status and development. We give below a template to receive your advice on what you see as the challenges in your sector, and how ICT can respond to these.
Please copy this template if you are interested in responding to more than one sector.
(The tables below will expand as you type.)

Name: Affiliation:
Contact Information email: fax:

Sector of Interest: _____

1. What do you find are the six developmental challenges relevant to this sector (in decreasing order of importance)?

It would help if your response addresses the following dimensions pertinent to the sector: availability, access, affordability and, quality.

Areas	Challenges
1	
2	
3	
4	
5	
6	

2. What do you see as the barriers in solving the challenges mentioned above (such as political, institutional, financial, technological, social and behavioral barriers)?

Challenges	Barriers	How they affect the issues?
1		
2		
3		
4		
5		
6		

3. Based on the description of the IC technologies provided (and others that you are aware of), are appropriate ICT available for these tasks? If not, what developments you think are needed in IC technologies for this sector?

Barriers	ICT availability	Developmental needs in ICT
1		
2		
3		
4		
5		
6		

4. Do you know of any ongoing ICT-enabled programs in this sector and what are your observations?

Area	ICT enabled program	Organization	Comments/Observations
1			
2			
3			
4			
5			
6			

5. What supporting infrastructure, institutions, or user-skills do you feel are required or need to be improved? Please prioritize the changes required (such as institutional, social, financial, technological etc.) to ensure rapid deployment of ICTs in this sector.

Changes or improvements required
1
2
3
4
5
6

6. Do you have other suggestions on what you want from ICT?

1
2
3
4

Many thanks. Please email your response to vsa@cmu.edu and with a copy to tongia@cmu.edu by December 10, 2003. If you wish to fax, please send this to: +1(435) 518 9710 (email is preferred).

Questionnaire for Information Communication Technologies for Agriculture (Food, Fiber and Fisheries)

Note: The workshop website (http://www.cs.cmu.edu/~rtongia/itsd.htm) gives information on the Workshop agenda and on ICT status and development. We give below a template to receive your advice on what you see as the challenges in agriculture, and how ICT can respond to these.
(The tables below will expand as you type.)

Name: Affiliation:
Contact Information email: fax:

1. What six major challenges do you see in the agricultural sector in developing countries (in decreasing order of importance)?

It would help if your response addresses the following dimensions: environmental, resource (land, water, other inputs), consumption patterns and demand, trade and market.

Areas	Challenges
1	
2	
3	
4	
5	
6	

2. What do you see as the barriers in solving the challenges mentioned above (such as political, institutional, financial, technological, social and behavioral barriers)?

Challenges	Barriers	How they affect the issues?
1		
2		
3		
4		
5		
6		

3. Based on the description of the IC technologies provided (and others that you are aware of), are appropriate IC technologies available for these tasks? If not, what developments are needed in IC technologies for agriculture?

ICT availability (ref. Q1)	Barriers	Developmental needs in ICT
1		
2		
3		
4		
5		
6		

4. Do you know of any ongoing ICT-enabled programs in agriculture, and what are your observations?

Area	ICT enabled program	Organization	Comments/Observations
1			
2			
3			
4			
5			
6			

5. What supporting infrastructure, institutions, or user-skills do you feel are required or need to be improved? Please prioritize the changes required (such as institutional, social, financial, technological etc.) to ensure rapid deployment of ICTs in this sector.

Changes or improvements required
1
2
3
4
5
6

6. Do you have other suggestions on what you want from ICT?

1
2
3
4

Many thanks. Please email your response to vsa@cmu.edu and with a copy to tongia@cmu.edu by December 10, 2003. If you wish to fax, please send this to: +1(435) 518 9710 (email is preferred).

Questionnaire for Employment Generation and Poverty Reduction

Note: The workshop website (http://www.cs.cmu.edu/~rtongia/itsd.htm) gives information on the Workshop agenda and on ICT status and development. We give below a template to receive your advice on what you see as the challenges in employment generation and poverty reduction, and how ICT can respond to these. (The tables below will expand as you type.)

Name: Affiliation:
Contact Information email: fax:

(I) Employment Opportunities in ICT

1. What skillsets do you consider necessary for ICT employment (in decreasing order of importance)?

Skillset
1
2
3
4
5

2. What skillsets are available in your country for ICT employment and what are missing?

Skillset	Availability	
	Urban	Rural
1		
2		
3		
4		
5		

3. What are the barriers to acquiring these skillsets?

Barriers to acquiring (Ref. Q1)
1
2
3
4
5

4. What are your suggestions to overcome these barriers?

Overcoming skillset barriers (Ref. Q3)
1
2
3
4
5

5. What resources are required to develop these skillsets? Do you have any suggestions for for country developing these skillsets (e.g., bilateral agreements including south-south, technology transfer, specialized academies, etc.)?

Skillset	Resources Required
1	
2	
3	
4	
5	

Skillset	Method of Developing
1	
2	
3	
4	
5	

(II) Employment Opportunities enabled by ICT

1. What sectors of your economy can benefit in the short term from ICT applications?

1
2
3
4
5

2. What sectors of the economy are currently benefiting from ICT? What organizations use ICT, and what types of ICT are being used? Do you have any further details or insights into any specific projects?

Area	ICT enabled program	Organization	Comments/Observations
1			
2			
3			
4			
5			

3. What sectors do you see opportunities to expand and develop markets through ICT?

1
2
3
4
5

4. What are the barriers to the use of ICT in these sectors (Ref. Q3 above)?

1
2
3
4
5

5. What are your suggestions to overcome these barriers in these sectors?

1
2
3
4
5

6. What suggestions do you have for making ICT more relevant for employment addressing national needs?

1
2
3
4
5

7. Do you have other suggestions on what you want from ICT?

1
2
3
4
5

Many thanks. Please email your response to vsa@cmu.edu and with a copy to tongia@cmu.edu by December 10, 2003. If you wish to fax, please send this to: +1(435) 518 9710 (email is preferred).

Questionnaire on the Role of ICT in Governance and Empowerment

Note: The workshop website (http://www.cs.cmu.edu/~rtongia/itsd.htm) gives information on the Workshop agenda and on ICT status and development. We give below a template to receive your advice on what you see as the challenges in the area of governance and empowerment, and how ICT can respond to these.
(The tables below will expand as you type.)

Name: Affiliation:
Contact Information email: fax:

1. Where do you think ICT can play a positive role in governance? Are you aware of any specific IC Technology that can enhance citizen empowerment?

IC Technology	Governance / Empowerment Role
1	
2	
3	
4	
5	

2. What are the barriers to implementing IC Technologies in governance?

1
2
3
4
5

3. What are your suggestions to overcome these barriers?

1
2
3
4
5

4. How do you see the role of ICT in empowering women? What initiatives do you recommend for such empowerment?

ICT Role	Initiatives
1	
2	
3	
4	
5	

5. How can we bridge the divide between ICT haves and have-nots? Do you have any specific suggestions for ensuring the "first-movers" do not increase their advantage?

Bridging the Divide	Suggestions and Comments (incl. 1st mover)
1	
2	
3	
4	
5	

6. Can you suggest ways ICT can help improve transparency and reduce transaction costs/corruption (in decreasing order of importance)?

1
2
3
4
5

7. Please list (in decreasing order of importance) the areas where ICT can most help (e.g., voter registration, health records, land records, taxes, driver licensing, etc.)

1
2
3
4
5

8. Do you have other suggestions on what you want from ICT?

1
2
3
4
5

Many thanks. Please email your response to vsa@cmu.edu and with a copy to tongia@cmu.edu by December 10, 2003. If you wish to fax, please send this to: +1(435) 518 9710 (email is preferred).

Appendix 6: Acronyms

3G	3rd Generation (of Mobile Telephony – capable of high-speed data)
AICTE	All India Council for Technical Education
AIDS	Acquired Immune Deficiency Syndrome
ARPA	Advanced Research Projects Agency (USA)
ASCII	American Standard Code for Information Interchange
B2B	Business to Business
B2C	Business to Consumer
BOP	Bottom of the Pyramid
CAIDA	Cooperative Association for Internet Data Analysis
CDAC	Center for Development of Advanced Computing (India)
CDMA	Code Division Multiple Access
CEE	Central and Eastern Europe
CERTs	Computer Emergency Response Teams
CGIAR	Consultative Group on International Agricultural Research
CIS	Commonwealth of Independent States (formerly the USSR)
CMU	Carnegie Mellon University
CO_2	Carbon Dioxide
CRT	Cathode Ray Tube
CSIR	Council for Scientific and Industrial Research (India)
CSTEP	Center for Study of Science Technology and Policy (India)
DAI	Digital Access Index (ITU Metric for data connectivity)
DARPA	Defense Advanced Research Projects Agency (US government entity that funds extensive R&D; its predecessor funded what became the Internet)
DHS	(US) Dept. of Homeland Security
DNS	Domain Name Service
DSL	Digital Subscriber Line
DST	Dept. of Science and Technology (Govt. of India)
e-commerce	Electronic commerce
ENUM	Electronic Numbers (New mechanism for linking Internet addresses to telephone numbers)
ESTI	European Telecommunications Standards Institute
FAO	Food and Agricultural Organization
FCC	Federal Communications Commission (USA)
FOSS	Free and Open Source Software
GDP	Gross Domestic Product
GIS	Geographic Information System
GNI	Gross National Income
GNP	Gross National Product

GPRS	General Packet Radio Service (considered 2.5 Generation mobile technology)
GPS	Global Positioning System
GSM	Global System for Mobile Communications (cellular phone technology)
ha	Hectare
HAART	Highly Active Antiretroviral Therapy
HCI	Human-Computer Interface
HDI	Human Development Index
HDR	Human Development Report
HIPC	Heavily Indebted Poor Country
HIV	Human Immunodeficiency Virus
HP	Hewlett Packard
HW/SW	Hardware/Software
IBM	International Business Machines
ICANN	Internet Corporation for Assigned Names and Numbers
ICT	Information and Communications Technology
ICT-SD	Information and Communications Technology – Sustainable Development
IDNs	Internationalized Domain Names
IETF	Internet Engineering Task Force
IISc	Indian Institute of Science
IP	Internet Protocol
IPR	Intellectual Property Rights
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
ISPs	Internet Service Providers
IT	Information Technology
ITU	International Telecommunication Union
kbps	Kilobits per second
LAN	Local Area Network
LCD	Liquid Crystal Display
Mbps	Megabits Per Second
MCIT	Ministry of Communications and Information Technology (India)
MDG	Millennium Development Goal
MEMS	Micro-Electromechanical Systems
MIMO	Multi-Input Multi-Output
n.a.	Not Available
NGO	Non-Governmental Organization
NIAS	National Institute for Advanced Studies
NIST	National Institute of Standards and Technology (USA)
NSF	National Science Foundation
ODA	Official Development Assistance

OECD	Organization for Economic Co-operation and Development
PC	Personal Computer
PPP	Purchasing Power Parity (mechanism for adjusting exchange rates based on local costs of living)
PTT	Post, Telephone, and Telegraph (Governmental telecommunications provider)
R&D	Research and Development
RFID	Radio Frequency Identification Device
ROI	Return on Investment
SCADA	Supervisory Control And Data Acquisition
SD	Sustainable Development
SMS	Short Message Service
T&D	Transmission and Distribution (e.g., of electricity)
TB	Tuberculosis
TCO	Total Costs of Ownership
TCP/IP	Transmission Control Protocol/Internet Protocol
TV	Television
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Program
UNICEF	United Nations Children's Fund (formerly United Nations International Children's Emergency Fund)
US	United States
USO	Universal Service Obligation
VCR	Video Cassette Recorder
VoIP	Voice over Internet Protocol
VSAT	Very Small Aperture Terminal (satellite communications)
WB	World Bank
WEHAB	Water, Energy, Health, Agriculture, and Biodiversity (UN Framework)
WHO	World Health Organization
WiFi	Wireless Fidelity (standard for wireless LANs – based on IEEE 802.11)
WiMax	Worldwide Interoperability for Microwave Access (standard for broadband wireless access – based on IEEE 802.16)
WSIS	World Summit on the Information Society

About the Authors

Dr. Rahul Tongia is a research faculty member of the School of Computer Science (ISRI) and the Dept. of Engineering and Public Policy at Carnegie Mellon University. His interests are interdisciplinary covering technology and policy, especially for infrastructure development. He holds a Bachelor of Science in Electrical Engineering and a Ph.D. in Engineering and Public Policy.

Dr. Eswaran Subrahmanian is a Research Professor at Carnegie Mellon University and Scientist at the US National Institute of Standards and Technology (NIST). His interests are in design, innovation, information systems, and knowledge management. He holds a Bachelor of Engineering in Chemical Engineering, a Masters in Computer Science, and a Ph.D. in Urban and Public Affairs (Information Systems).

Dr. V. S. Arunachalam, a Distinguished Service Professor at Carnegie Mellon University, is Vice-Chairman of the Planning Commission, Tamil Nadu State, India, and Founder, Center for the Study of Science, Technology, and Policy (CSTEP), a Bangalore-based not for profit Think Tank.