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.

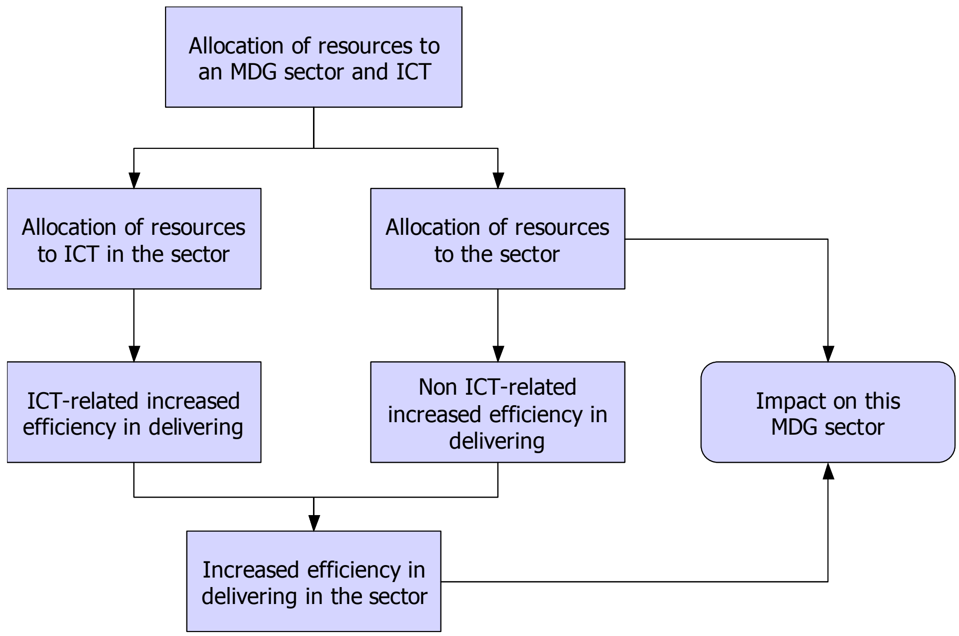
ICT and Development

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

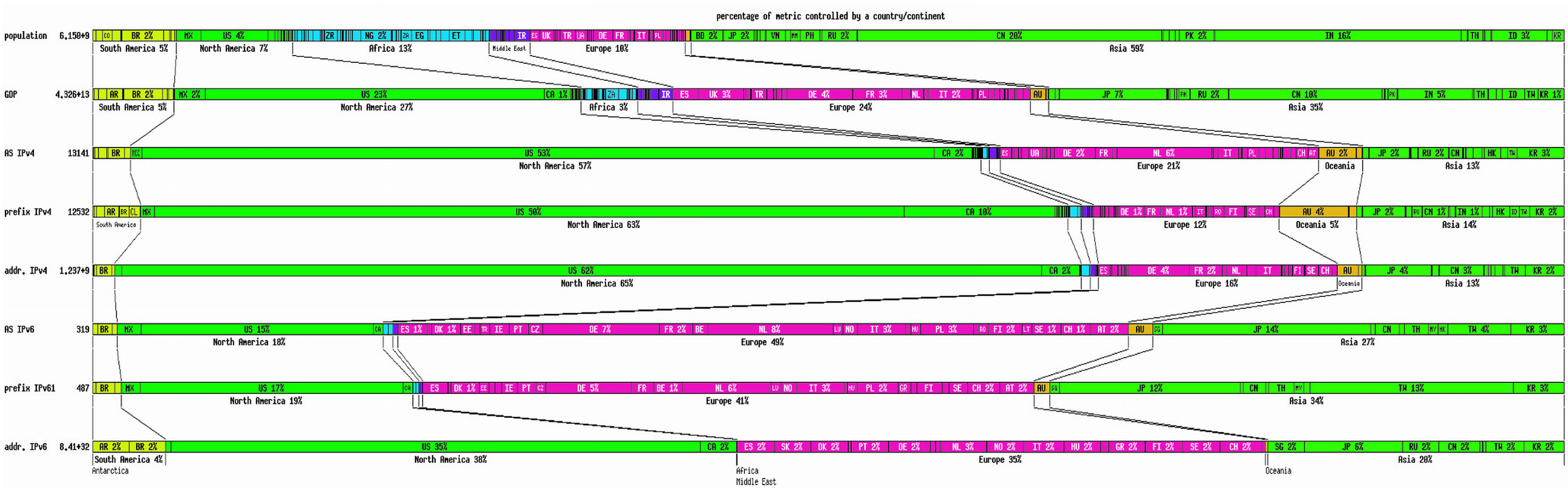
The birth and the growth of the Internet were in the United States, and this has led, in part, to large distortions in connectivity between the developed and developing nations. However, economics remains the obvious overarching reason for the continuation of the divide. Data from the Cooperative Association 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.

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

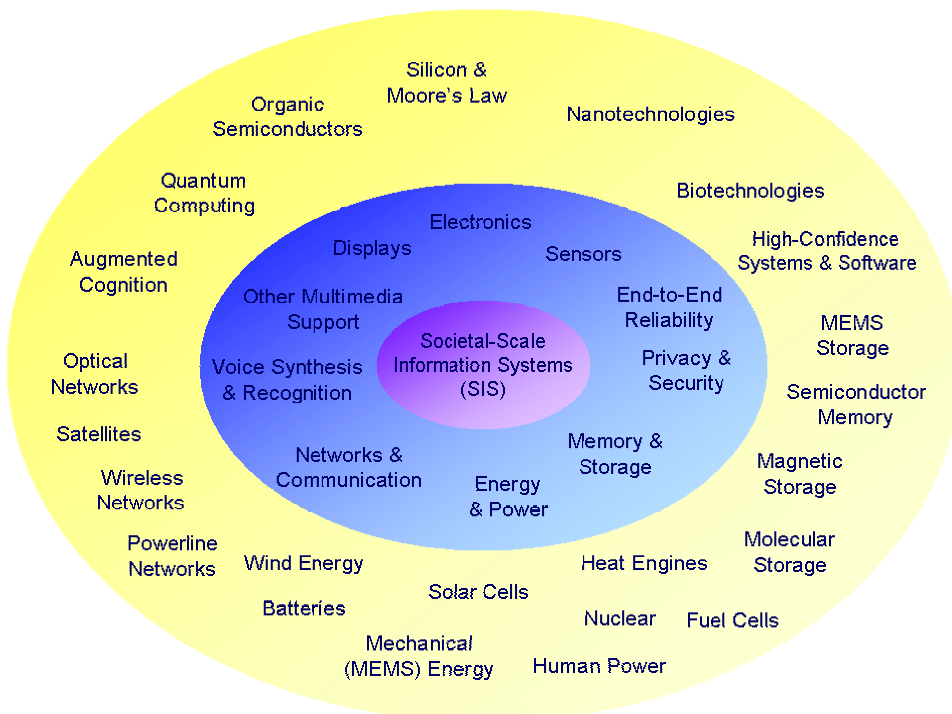
Does this imply that to make ICT affordable, we need just to wait? Halfway, and interim solutions that are incomplete can cause great harm, creating legacy requirements and vested interests. A thoughtful, forward-looking technology roadmap and new solutions are required. There remain a number of questions 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.

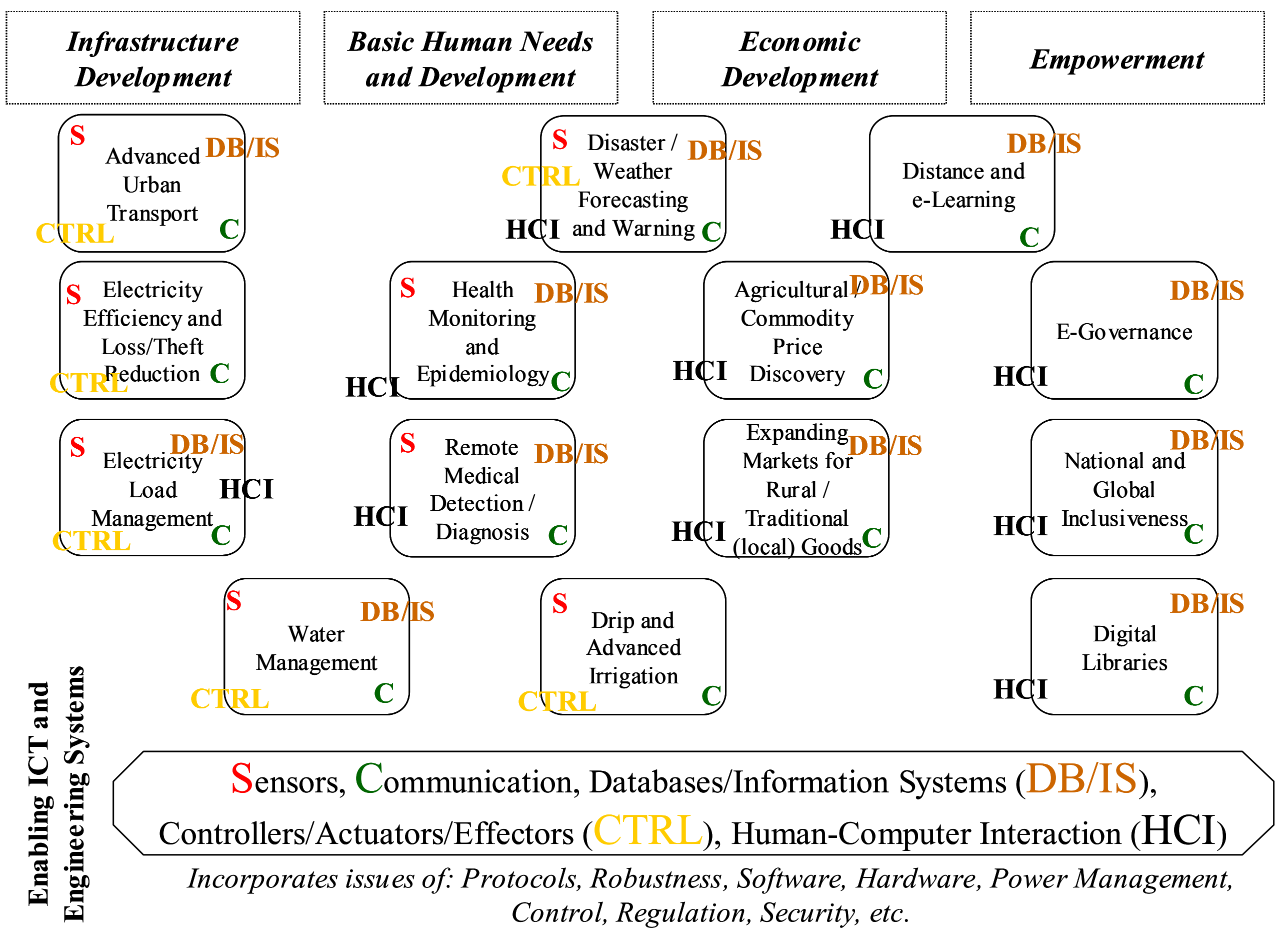


Figure 5: Select Examples of End-use Needs Driving ICT. Shown are the primary ICT components as per the generalized model (Table 3), but almost all components play a role in any real-world system.

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

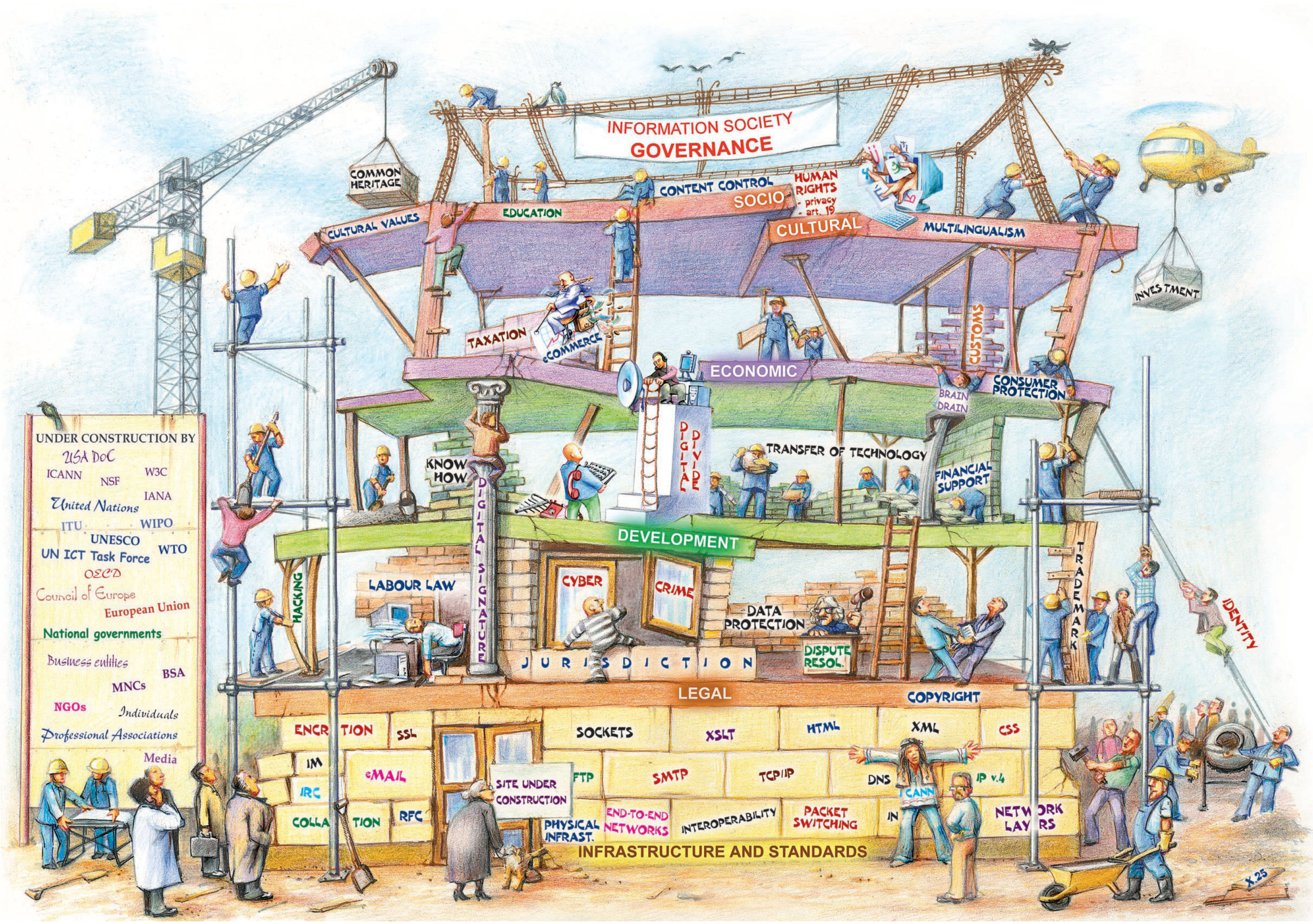
---

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.