SCIENCE AND TECHNOLOGY INPUTS FOR INFORMATION AND COMMUNICATION INFRASTRUCTURE DEVELOPMENT IN SRI LANKA

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Abstract

New information and communication technologies will arrive on the market at a fast and furious pace. Two technologies of immediate relevance to information and communication infrastructure (ICI) development are broadband access and secure servers. Emerging features of an ICI include distributed computing and associated communications; sophistication of end-devices through links to global positioning systems, sensors that detect and transmit environmental conditions, unique identity systems; and Public key infrastructures for secure and authenticated commercial transactions or e-commerce.

ICI developments in Sri Lanka will continue to be driven through private sector investments. An ICI develops in response to the supply of technologies and the demand by users. Given the pace of technology developments and the globalized nature of markets, the most important S&T input to ICI development is a workforce that is able to take the technologies and provide innovative solutions to e-business, e-government, and e-society uses of an ICI. In the long-term, the country needs to develop some capacity to innovate. In S&T capacity building strategies the role of the private sector is often underestimated, attempts are made to develop 'appropriate' technologies where they do not make economic sense, and public–private partnerships are prescribed for situations where the public sector simply does not have the S&T capacity necessary for such partnerships.

We propose a strategy where the role of the government is to (a) provide an environment that enables industry to build their own R&D capacity through trade, direct foreign investment (DFI) or licensing relationships, (b) recognize that the universities in Sri Lanka are essentially teaching institutions and ensure that these institutions focus on preparing an innovative workforce, (c) nurture existing pockets of research excellence in the public sector that contribute to new knowledge, product development, or education and training; phase out other investments, (d) liberalize policies for private-public partnerships and (e) assess the performance of public and private sectors on a continuing basis through comparisons with institutions in other countries and loop back that information to the policy-making and funding processes.

1. INTRODUCTION

Information and Communication Infrastructure (ICI) Development is a priority for Sri Lanka. The 2002 budget speech made by the Minister in charge of Information Technology underscored the importance placed by the government on this issue. He said :

"I want to move on to the prospect of a new Sri Lanka created through Information Technology. Some of you may view the next few minutes as a dream. But the reality is that if we are to achieve the 10% growth our Prime Minister is targeting, or even a lesser amount of 7%, then we need to fulfill this dream. For, without a commitment to succeed in the field of Information Technology, we have little choice other than to be a backwater forever more.

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Our aim should be to create a new [ICT] infrastructure. In telecommunications, we shall need to examine ways in which we can remove entry barriers . . . In particular, we need to ensure competition and provide quality services at the lowest price to encourage maximum penetration. . . . We find that as technologies develop and converge, traditional boundaries and paradigms are shifting. Today, your communications, information, and entertainment mediums are converging. Tomorrow, the only device which we will require may be a hand phone which will serve as a computer, television, and an all-purpose communication device, all rolled into one.[1]*"*

This awareness is widespread. Indicators have been developed to measure the adequacy of Internet connectivity. One of the most recognized indicators is 'e-readiness', defined as the ability of a country to connect to the Internet and interact with a networked world [1]. The condition of a country's Information and Communication Infrastructure (ICI) is critical for its overall e-readiness.

This report focuses on the S&T inputs that can improve performance of the ICI, rather than on regulatory or other actions. To an extent, the regulatory and policy environment has to be assumed.

In **Section 2,** we describe some features of an e-ready ICI and briefly S&T inputs relevant to an e-ready ICI. E-readiness is an evolving concept. Features of current relevance are described, followed by emerging features. Considering that Sri Lanka trails the U.S., Europe and the newly industrialized Asian countries even in basic telephone coverage, the relevance of a discussion of cutting-edge technologies may be questioned. They are presented for several reasons. First, information and communication technologies, properly deployed, have the potential to transform the economies of the developing world, through leapfrogging [1, 2]. Secondly, Sri Lanka has been a world leader in improving the performance of its telecom sector, ranking only behind China in combined fixed and mobile teledensity compound annual growth for 1995-2001[2]. It is not inconceivable that given the right policies and conditions similar success may be achieved in ICI development.

In **Section 3** we will place some of the technologies in context through a discussion on their application in several sectors. We will look at five major sectors that have the potential to be enabled by ICT. They are trade & industry, environment, health, education, and research and development (R&D). Within the trade and industry sector we will look closely at the information and communication technology and food and agriculture sectors.

In **Section 4** we identify some of the factors that affect the S&T inputs to ICI development and in **Section 5** we identify ways of rectifying some of the problems. In order to place the discussion in perspective, we look at both S&T and non S&T factors. We take a critical look at some of the accepted wisdom of S&T inputs to industrial development. We present the argument that currently both the public and private S&T bases are weak and that attempts to forge partnerships between these two sectors will be counter productive at this stage of development in Sri Lanka. We propose a hands-off, incentive based approach to enhance the S&T capabilities of the public and private enterprises. The 'soft' side of ICI could be one area where university-industry partnerships might be productive and therefore we address the 'hard' and 'soft' aspects of ICI development separately. We summarize our recommendations in **Section 6**.

2. SOME FEATURES OF AN E-READY ICI AND RELEVANT INPUTS

2.1. ICI Technologies

Information and Communication Infrastructure grew as extensions to existing telecom networks. Today's ICI is a far cry from the original telephone network which carried voice from one telephone to another through copper wire based switched networks. Connecting computers as peripherals and developing protocols for these computers to communicate with each other marked the beginnings of the Internet. Development of the World Wide Web (a system of Internet servers that support specially formatted documents) and protocols for communication between devices transformed the Internet from a network primarily used by researchers to a global information system driven by commercial imperatives. The demand for access to the Internet and the supply of

[1] Speech delivered by Hon. Milinda Moragoda during the Appropriation Bill 2002 – Committee Stage debate on the Ministry of Economic Reform, Science and Technology on 10 April 2002

[2] China 34%, Sri Lanka 29%, Botswana 27%, Ghana 27%, Tanzania 27% -Calculation by Johannes Bauer, ITU, 2002 data

technologies capable of providing increasingly faster access are two reinforcing trends that lead to the further transformation of telecom networks into ICIs [3].

Current national and international ICIs are made up of telecom and data networks and services. Telecom and data networks are made up of a variety of access technologies connecting a variety of peripheral devices. Enabling practices and protocols facilitate the connections. The availability and the affordability of access technologies largely determine how individuals and organizations use the Internet to provide or use increasingly sophisticated services. The activities enabled by an ICI can be broadly classified as e-commerce, e-government, and e-society. The peripheral devices and ICI enabled activities, in addition to the network, are components of the ICI because access technologies, enabling technologies, peripheral devices, and enabled activities co-evolve, each affecting the whole. In the next few paragraphs some of the technical developments in the four components of an IC backbone capacity, access technologies, peripheral devices, and enabling protocols and practices are discussed.

2.1.1. Backbone Capacity

The Internet, like the old telephone system, is an inherently global network. However, the predominant information-retrieval functions of the Internet accentuate its global nature. As recently as 1997, only 10 percent of the Sri Lankan incumbent fixed telecom operator's customers had IDD [International Direct Dialing] facilities and the rest were effectively shut out from most of the calling opportunities afforded by the system. It is difficult to imagine that 90 percent of Internet customers would accept a service that prevented them from accessing information outside the country or communicating with those located abroad. Most of the attractive content of the Internet is located, for historical and other reasons, in the United States. Until recently, there was no Internet interconnection point within Sri Lanka. That meant that even an e-mail from one Sri Lankan user to another (who was a customer of a different service provider) had to be delivered via the Internet backbone. For all these reasons, Internet service provision requires operators to have cheap, efficient connectivity to the Internet backbone.

Backbone connectivity requires leased lines—lines that are dedicated to a particular use or user and that can be enhanced by multiplexing and other techniques. An international leased line can be provided via satellite or via an undersea cable (high frequency wireless transmissions were used in the past, but are now obsolete). In the early days of satellite, it was considered inferior to undersea cable because of the delays caused by 84,490 km transit via a satellite in the geostationary Clarke orbit. Now, the delays in single-hop transmissions have been pretty much eliminated by technical means and no user can distinguish between a voice conversation using a high-quality satellite link from one that uses an undersea cable. A single hop can take a call from Sri Lanka to Europe on one side and Japan on the other. A double hop (a distance of 168,980 km) is required to go to the United States and will result in deteriorated quality. Generally, traffic to the US utilizes satellite to Europe and undersea cable across the Atlantic, or satellite to Japan and undersea cable across the Pacific.

There is a glut of undersea cable capacity across high-traffic routes such as across the Atlantic and the Pacific. As a result, prices are low and quality is excellent. The opposite is true in Sri Lanka. There is only one cable (SEA-ME-WE) landing in Sri Lanka and has so far been monopolized by the fixed incumbent. Most, if not all of the traffic to the Internet backbone is therefore routed via satellites, access to which was liberalized by the government in 1999. There is no shortage of satellite capacity over the Indian Ocean.

Within the country, operators require access to backbone capacity to provide nationwide service. In an environment such as Sri Lanka, where the demand is growing very fast, there is always a possibility that this capacity will be inadequate and will result in congestion and delays. The current policy is to allow a large number of operators the right to "build or buy." That is, all three fixed operators, all four mobile operators, and four data operators have the right to build their own long-haul capacity, though they are not prohibited from "buying" or leasing capacity from any of the others who are authorized to build and from the specialized infrastructure provider whose sole business is providing capacity to other operators. The ISPs [Internet Service Providers] who are known as non-facilities based data operators, do not have the build option, but have the choice of buying capacity from a large number of suppliers. Theoretically, the above-described environment should result in low prices and good quality, but from the complaints of the non-facilities based operators, it appears that anti-competitive practices by fixed operators and the lack of alternative capacity, especially on the thin routes, is yielding a less than optimal outcome.

Supplementing backbone capacity requires the use of right of way for underground or overground cables, the availability of frequencies for microwave transmission, and the building of

microwave towers in technically optimal locations. Frequencies are managed, not optimally but not disastrously either, by a single, well-resourced national entity, the Telecommunications Regulatory Commission of Sri Lanka. Multiple government authorities exercise jurisdiction over rights of way and locations for antenna towers. Their approval processes are rife with opportunities for the exercise of discretion in arbitrary and capricious ways.

2.1.2. Access Technologies

High bandwidth connections are necessary to access an increasingly sophisticated range of Internet services available to consumers and businesses. The bottlenecks are usually at the 'last mile' that connects high capacity national networks to a home or a business. Although national networks have the capacity to bring broadband to homes and businesses, the majority of Internet subscribers use regular telephone lines to access the Internet.

2.1.2.1. Fixed Broadband

ISDN (Integrated Services Digital Networks), DSL (Digital Subscriber Line) and Cable modem access are of the principal fixed broadband options being rolled out in the developed countries today. The first step up from a standard telephone circuit in terms of improving network access speed for residential customers is ISDN, with an equivalent capacity of 2-4 circuits. In some countries users are moving directly to higher capacity DSL services. Reconfiguring existing copper wires as ISDN lines or DSL is a logical option for countries that have reached saturation levels in telephone penetration. In countries where cable TV is widely available and the wiring is of adequate standard, broadband access through add-ons to existing cable networks may be the preferred option.

Ideally, networks would have optical fiber throughout, not only on the trunk routes, but also in the last mile. Optical fiber has enormous capacity, which is being enhanced by techniques such as Dense Wave Division Multiplexing (DWDM) that allows for the simultaneous carriage of 80 data channels on a single fiber optic cable. In countries such as Sri Lanka where there is no ubiquitous pre-existing network, the economics of fiber versus coaxial and copper are quite different from that in developed countries.

For example, cable entrepreneurs in Sri Lanka are stringing aerial fiber along the streets of Greater Colombo, instead of coaxial cable. The backward nature of the Sri Lankan cable industry, way behind developments in India and even Bhutan, may in the end turn out to be a blessing. It may be noted that the reason for the slow development of cable networks in Sri Lanka was the profligate issuance of licenses and frequencies for over-the-air broadcasting in the 1990s.

ISDN and DSL were developed for mature markets where almost all locations were already connected to the telecom network. ISDN is an old technology. The original CCITT recommendation for ISDN was issued in 1984. It never caught on in the US and is now effectively eclipsed by DSL. Europe and Japan were enthusiastic about it, which may be the reason why the Sri Lankan operators with Japanese and Swedish management rolled out this semi-obsolete technology in Sri Lanka with great fanfare in 1999. In ISDN, voice and data are carried by bearer channels (B channels) occupying a bandwidth of 64 kb/s (kilobits per second). Some switches limit B channels to a capacity of 56 kb/s. A data channel (D channel) handles signaling at 16 kb/s or 64 kb/s, depending on the service type. A 64 kb/s channel carries data at a rate of 64000 b/s.

DSL is a technology that exploits unused frequencies on copper telephone lines to transmit traffic typically at multi-megabit speeds. DSL can allow voice and high-speed data to be sent simultaneously over the same line. Because the service is "always on," end-users do not have to dial in or wait for call set-up. ADSL (Full Rate asymmetrical DSL) can be configured to deliver up to six megabits of data per second (6000K) from the network to the customer; that is up to 120 times faster than dialup service and 100 times faster than ISDN. ADSL enables voice and high-speed data to be sent simultaneously over an existing telephone line. This type of DSL is the most predominant in commercial use for business and residential customers around the world. ADSL was trialed in Sri Lanka by the dominant operator only in mid 2002. There are several other variants of DSL, including symmetrical and high data rate versions.

Sri Lanka was an innovator in fixed wireless technology in 1996. It licensed two national fixed operators who were not allowed to use wireline connections to their customers. In 1996, there was much hype around DECT [Digital European Cordless Technology], which was seen as likely to repeat the success of the European GSM standard. One of the Sri Lankan fixed wireless operators selected DECT while the other opted for a proprietary Nortel standard known as Proximity. DECT did not catch on worldwide for multiple reasons, the most relevant being its poor performance in terms of

data transmission. Faced with strong demand for high-speed data connectivity from its corporate customers, the DECT operator adopted a different technology as an overlay on the existing network.

The proprietary standard was superior to DECT, but even that operator adopted an overlay strategy in 2002. The difficulties experienced by fixed wireless broadband operators in the major markets of the US and Europe have dimmed the hopes of lower costs that would come from high-volume production.

2.1.2.2. Mobile Broadband

Nicholas Negroponte put forward the thought-provoking proposition that all that is now carried on wires should move to wireless and all that is now carried without wires should move to wires. What he meant was that bandwidth hungry applications such as television should be delivered through channels best suited for that purpose, namely fiber cables, and that services such as voice telephony and messaging, that were traditionally carried on wires should move to wireless media that were capable of reaching people instead of places, optimizing the mobility features of the transmission medium. The dominance of cable delivery for television content in developed countries (despite the wasteful hogging of frequencies by politically powerful broadcasting interests) and the fact that mobile telephones now outnumber fixed telephones worldwide indicate that the Negroponte Proposition is being proven correct.

The Negroponte Proposition rests on matching applications to the comparative advantages of a particular transmission medium. Wireless transmission using electromagnetic frequencies is uniquely capable of reaching people on the move. Fiber or coaxial cable is best suited to carry large volumes of data at high speeds. To carry equivalent data volumes at high speeds without wireguides would require major allocations of scarce frequencies in addition to the solution of several other technical and economic problems. The current debates about the viability of Third Generation (3G) mobile telephony, envisaged as a marriage of mobile telephony and the Internet, are pertinent to the Negroponte Proposition.

The technical standard that drove the explosion of mobile telephony in the past decade was GSM [Global System for Mobile Telephony]. It was called second generation because it was a digital standard that followed a host of analog standards and was qualitatively different. Sri Lanka began mobile telephony in 1989 with an analog standard, which was what was available at the time. At the time 2G arrived in Sri Lanka in the mid 1990s, the four mobile operators used three different standards, GSM, AMPS, and E-TACS. The fact that the last operator to enter the market and the first to adopt GSM is now the market leader and that all four mobile operators are now using or moving to GSM, indicate that Sri Lanka is now a 2G country. The relatively low take up of SMS [Short Messaging Services], an appendage of digital mobile that has exploded in use worldwide - in Sri Lanka suggests that the full potential of 2G is yet to be realized.

3G, also described as IMT-2000 and UMTS, was to use frequencies in higher bands to provide always-on mobile connectivity that would add information retrieval functions to the conventional messaging features of mobile telephony. In essence, the idea was to marry two explosively popular technologies-mobile telephony and the Internet. The auction of frequencies for 3G started in 2000 and drew enormous attention because of the astronomical amounts of money they raised for the UK and German governments. However, neither the services that could be offered nor the pricing paradigm had been conceptualized. Internet access requires “always-on” connectivity, content worth accessing and handsets that can display the content in attractive and usable form. 3G offered always-on connectivity but at much lower speeds than people were accustomed to from their desktops. The question of whether retail pricing should be on the basis of a flat fee or on the basis of bits downloaded has not yet been resolved. Content for mobile handsets has to be designed with the requirements of mobile users and the limitations of the terminal device and connectivity in mind. It cannot simply be existing Internet content. In addition, the financing of content and the pricing for content is still an open question, except to a certain extent in Japan, which introduced an early form of 3G known as I-Mode. These difficulties were compounded by the shortsighted efforts of governments to extract the maximum possible revenues from the 3G auctions and the complicity of mobile operators and their financiers, at least in the early stages of the process. The interest burden of the multi billion-dollar payments combined with the end of the “dot.com bubble” to slow down, if not stall, 3G developments. It appears that the Negroponte Proposition still holds.

Current thinking on 3G applications focuses less on Internet connectivity (though it is not excluded) and more on the synthesis of mobile connectivity with positioning technologies such as GPS

[Global Positioning System], originally designed for the US military. A mobile handset that establishes the location of the user based on GPS signals and provides tailored information for that location such as maps, shopping, eating or entertainment opportunities exemplifies the current thinking. The user can then communicate with a nearby hotel to make a reservation. The handset can also serve as a payment device. The user can make the payment using the handset itself, without having to read out a credit card number.

Sri Lanka has not issued any licenses or frequencies for 3G. Because 3G involves the licensing of the right to use a scarce resource, current Sri Lankan law requires that the process be conducted in a transparent and fair manner, unlike the issuance of the 2G licenses. The solicitation of competitive bids for 3G licenses does not necessarily require the extracting of massive amounts of money from the bidders. Hong Kong and Denmark, which conducted their 3G auctions in 2001 have shown how transparent and fair allocations of frequencies can be done without driving operators to near bankruptcy.

Wi-Fi is an emerging technology using an unregulated "open" frequency range. It basically allows wireless connectivity to a small, low-cost wireless equipped server in an office or residence that is connected via conventional broadband means to an Internet Service Provider. In the simplest form, it allows anyone within the residence/office to access the Internet without physically connecting a wire to the computer or access device. In the enhanced form, it allows anyone within a limited geographical range of the server to access the Internet. That is, strangers sitting in a neighborhood coffee shop can access the Internet Service Provider of a Wi-Fi equipped residence/office. The most advanced form of Wi-Fi allows for the building of contiguous Wi-Fi islands that would, for example, allow a person traveling on a highway to access the Internet entirely on the facilities of hospitable strangers. The solution is attractive in terms of low cost and the building of social capital, but is problematic in terms of a sustainable economic base and safeguards against malicious attack and contamination. It is also threatened by changes in terms and conditions of service by ISPs who do not appreciate the higher than expected loads and loss of potential paid business.

2.1.3. Peripheral Devices

Peripheral devices can be fixed or mobile. Data communication through mobile phones and other mobile devices are still in the early stages of development and largely limited to technology enthusiasts [4]. Today such a person could carry several mobile devices—a cell phone and/or a device for tapping out email messages, pager, digital organizer, an MP3 player, and portable computer. Integration of multiple mobile devices into one convenient device is an area with much investor activity but so far no clear winner has emerged. A major obstacle for the success of these innovations is the misunderstanding of human factors involved. A human factor in engineering designs is an interdisciplinary area of research, which is bridging research in social sciences and engineering.

The nature of peripheral devices is changing in ways that would make them more than 'gizmos'. Integration of location, measurement, or authentication devices to all kinds of items ranging from containers to an air filter in an automobile can turn them into networked peripheral devices and transform business practices whereby every package, container, or any business process unit can be tracked and monitored [5]. These transformations are possible because of the plummeting costs of these technologies and the development of new protocols and software. One example of plummeting costs is the Radio Frequency Identification (RFID) tag - a tiny programmable chip that can relay information about the identity and location of the physical object to which they are attached – which currently costs about US$ 1 per unit. Several major initiatives that are currently underway are expected to reduce the cost of these tags to as little as US$ 0.03 per unit in the near future [6]. Countries, which are quick to incorporate these technologies to their manufacturing plants and the supply chain and transportation systems, will be at a competitive advantage.

2.1.4. Enabling Protocols and Technologies

A variety of enabling technologies facilitate communications through the networks made up of peripherals and access technologies. The development of the World Wide Web (www), unique address spaces based on the Internet Protocol (IP) and communications using the Transmission Control Protocol/Internet Protocol (TCP/IP) facilitated the early development of the Internet. With the demand for secure communications over the Internet 'Encryption Technologies' soon followed.

Two new developments - X-internet and public key infrastructure - are expected to further facilitate the evolution of the Internet. X-internet is highly touted by many as an alternative to the current www communication platform and is optimistically viewed as a way for developing countries to leapfrog into networked world [6]. The most important characteristic of the x-internet from a

developing country perspective is its ability to optimize data based on XML (Extended Markup Language) which contains lot more embedded information than HTML. The X Internet will also use a smart code such as Java and a distributed architecture to move applications execution closer to the user or the peripheral device. For example, at present the code is executed at the host server and the user software has to continually 'ping' the host server to get the results. This continuous back and forth transmission can use up a lot bandwidth. In X Internet, the processing logic is distributed between the host and the client and requires as little as 10 percent of the bandwidth capacity required to operate Web based applications. This characteristic de-emphasizes the importance of expensive broadband access technologies as a condition for advanced uses of the Internet and levels the playing field for developing countries. X Internet is also able to extend the use of ever cheaper sensors and other tagging devices to track the location, environment and the identity of distant objects.

Public Key Infrastructure (PKI) is a combination of technologies and authorizing entities that allow secure transactions to take place over a public network such as the Internet or a wireless Local Area Network (LAN) and is seen as vital to the use of the Internet for commercial purposes [7]. PKI goes beyond the current practice of each business creating its own system of secure servers to a standardized system that provides mutual authentication, data confidentiality, data integrity and non-repudiation features, providing the trust and security essential for faceless transactions that take place over the internet.

2.2. A Summary of ICI technologies

	Backbone and Access Technologies	**Peripheral Devices**	**Enabling Technologies**
Current	♦ Backbone (mostly copper wire) ♦ Fixed Narrow band access ♦ Wireless Narrow band	♦ Telephones (fixed or mobile) ♦ Computers	♦ WWW (HTML based) ♦ IP address protocols ♦ TCP/IP protocols ♦ Encryption to make servers secure
Emerging	♦ Backbone (mostly optical fiber) ♦ Fixed Broadband ♦ DSL ♦ Cable ♦ DWDM ♦ Wireless Broadband ♦ Wi-fi ♦ Other	Proliferation and possible integration of hand-held devices such as ♦ Cell phones ♦ Planners ♦ Audio devices ♦ Pagers ♦ E-mail Sophistication of devices through links to: ♦ Spatial data ♦ Sensors ♦ Unique identity systems	♦ X-Internet (XML based) ♦ Public Key Infrastructure for security

3. ICI NEEDS BY SECTOR

All businesses depend on basic information and communication features such as reliable phone services and fast Internet access. We will look closely at several sectors to identify special needs, if any, of those sectors and summarize the S&T inputs required to address those ICI needs.

3.1. Trade and Industry

3.1.1. Information and Communication Technology (ICT) Sector

The ICT sector is made up of businesses that provide ICT-based products and services such as call centers, IT training, hardware manufacture, and software development. Some ICT industries are more dependent on an ICI than others. Of the four types given here, only the call centers are significantly dependent on special IC features for its operation. Companies located in places with high

labour costs move their customer service departments to offshore facilities. Reliable and inexpensive direct links from client to service providers are key to success of these operations. These industries are perhaps the information age equivalents of garment manufacturing where Sri Lanka essentially provides the facilities and cheap labour. The value of these enterprises should not be underestimated. They provide jobs and bring immediate benefits of an ICI to people. The S&T input of most relevance to these operations would be to have ICI providers work with this industry to offer variations of mature technologies that will help the industries to remain competitive.

The other categories of ICT-based industries - IT training, hardware manufacture and software development - do not require special ICI features other than the basic ICI services. However, these three categories of IT industries, if developed as thriving sectors of the economy, could partner with ICI provider services in business relationships to add S&T inputs to ICI development in Sri Lanka (More on this in Section III).

3.1.2. Food and Agriculture

Market information is critical for growers/suppliers. A bumper crop of onions in Jaffna but not in another growing area is critical information for buyers in Colombo. The fact that there is a glut of onions in the Pettah market and a shortage of onions in the Galle market are time-sensitive information of critical importance for growers and shippers in Jaffna. Newspapers and radios that provide this information are intermediaries. As we discussed in Section I emerging technologies with peripheral devices that can track and report conditions from point-to-point at relatively low cost can connect those who have the information with those who it without the over reliance on intermediaries. The example here is given simply to demonstrate the concept. The feasibility of these methods has to be tried out by consumers. Technology is often not the factor that stands in the way of development.

The case of agribusiness and agricultural management support systems has been given considerable attention in the ICT and development community. Indeed, there appears to be scope for agricultural services based on user-fees (in addition to aggregation approaches as defined below). However, although market price information for the agricultural sector is often touted as a substantial value addition of rural Internet services, the promise and economic self-sustainability of such a service has recently been called into question (Aral *et al*. 2001). Market prices can be valuable, but their importance will depend on other community characteristics including availability of transport, credit, and alternative markets [8].

3.1.3. Other Trades and Industry

The most anticipated use of an ICI is in enhancing business processes in industry and trade which is commonly referred to as e-commerce. E-commerce can be business-to-business (B2B), business to government (B2G) or business to consumer (B2C.) For e-commerce to work, other types of e-activities such as e-government and e-society have to be viable to some extent. E-government is the use of the Internet by government to disseminate information to the business and the public, receive information from these groups, and generally enable governance. We use the term e-society to capture a multitude of uses of the Internet by individuals and groups. Individuals may use the Internet for personal communications, and for access to learning resources (e-learning), medical resources, and entertainment resources and for conducting business with the government, commercial enterprises or non-profit organizations. Generally, most of the ICI needs for e-government and e-business are subsets of e-business needs.

Given the importance of Internet connectivity to export industries, maximizing ICI use by businesses for export industries is critical. Leased lines, domestic and international, are vital inputs. Secure servers and mechanisms for assuring trust and confidentiality are needed for e-commerce.

There is also a tremendous demand to interlink different locations of business enterprises using broadband. Device to device communication that help businesses keep track of their business processes are yet to materialize in the form of affordable technologies, but businesses need to keep an eye on these developments.

Emerging technologies that connect devices to devices can help businesses keep track of their inventory, product processes, and the transport and the delivery of products. These technologies are certainly going to be important but it is hard to determine a time frame for their development.

3.2. Education

In developed countries ICTs are used to enhance the education sector in two ways:

- Enhancing the learning experience of those engaged in learning at traditional educational settings.
- Continuing education and expanding opportunities to those who have been left out of higher educational opportunities.

Enhancing the classroom learning experience through the use of ICT is an evolving concept. There is much experimentation in the developed world on this subject. Technology is only part of the solution to improving education. A culture of innovation in education is essential for educating the next generation for a knowledge economy. We discuss the importance of a culture of innovation in higher education later in this paper.

Of more importance here is the issue of expanding the opportunities for higher education to those who have been left out of the process. Although Sri Lanka ranks high among countries in terms of students finishing secondary education, only 1.4% of college age students are enrolled at tertiary institutions. According to the most recent international statistics available, Sri Lanka spends 0.8 percent of government spending on tertiary education [3], much less than the percentages allocated by Singapore (8.1%), Malaysia (3.3%) or Thailand (4.6%).

It is inconceivable that Sri Lanka can match other countries in the short term in educational spending. Therefore it is critically important to use private sources and IT technology to make higher education available to many more. Private education is not new to Asia. In Thailand, 40% of students are enrolled at private institutions. In Philippines it is 75%. In Singapore and Malaysia higher education has been largely a public sector activity until recently, but those two countries send a high number of their students abroad for higher education (Malaysia, 21.5%, Singapore, 19.7%). There is high resistance to private higher education by students and trade unions in Sri Lanka. The critical issue in the education sector is political, not technical. The government can play a crucial role in making cross-country comparisons and making the data available to the public for a broad-based discussion on expanding higher education opportunities in Sri Lanka.

3.3. Research & Development (R&D)

The Research and Development sector is critically important in a knowledge-based economy. Developing countries cannot afford not to innovate. According to the 2001 United Nations Development Program's (UNDP) Human Development Report entitled 'Making new technologies work for human development', it is stated that:

"Not all countries need to be on the cutting edge of global technological advance. But in the network age every country needs the capacity to understand and adapt global technologies for local needs."

The capacity to understand and adapt can be acquired through external training but it can be sustained only through domestic R&D. Connectivity to the global knowledge base is critical for effective domestic R&D. The Sri Lankan Educational and Research Network (LEARN) facilitates electronic connectivity between the academic and the research Community of all universities and also provides Internet access to staff and students. Connectivity to the Internet means that the research community in Sri Lanka does not have to limit itself to links with local researchers. As we discuss later in the paper, a global outlook is particularly important for research communities in small countries.

High-speed connectivity for the research communities is considered a priority in the developed world. In 1985, the NSF (US) decided to support Internetworking for research and education. By 1995, the Internet had become a worldwide system of more than 100,000 networks. NSF (US) retired the NSFNET backbone network service, transferring the provision of commodity Internet services to the emerging Internet industry, but in 1995, NSF authorized the creation of the vBNS, (Very High-performance Backbone Network System,) with initial connections to the NSF-supported supercomputing centers and Network access points (NAPs.) Support of high-speed research networks continues in the US, Europe and other developed countries. At this stage of development in Sri Lanka, the Sri Lankan research community needs basic internet access and other support such as allowances for travel and leave etc. that is needed to foster successful research collaborations, domestic and global.

3.4. Environment

The general public and interest groups together with businesses and government are the key actors in environmental management. For businesses, obtaining permits, submitting them and receiving response in a timely manner is critical. Accessibility to information for the public and interest groups ensures open and fair process of environmental management. The ICI needs of the environmental sector are essentially the needs for e-government—i.e., availability of government information on the Internet, ability to conduct transactions on the Internet and access to Internet by businesses, the public and nonprofit organizations.

There is much hope in the use of device-to-device technologies that incorporate location and environmental data in environmental management. The price tag on these devices will determine the viability of using these technologies for environmental management in Sri Lanka.

3.5. Health

Tele-medicine, tele-radiology and expert systems are some ICT applications in health [4]. These applications are relevant to the medical professionals. Applications of relevance to developing countries are in using the Internet to educate health care workers, eliminate isolation of healthcare workers in rural areas and provide health information to the general public. WebMD is a highly popular Web site maintained by the WebMD Corporation in the US. The WebMD Corporation is a company that sells software services to the healthcare industry. The Website is a public service effort by the company and is well regarded as a source of accurate information on health. The National Institutes of Health maintains a user-friendly website on all kinds of diseases. Many other non-profit organizations also maintain health information websites. These resources are available to anybody in the world with access to the Internet.

3.6. Summary

- The need for basic services such as reliable phone services and fast Internet access are common to all sectors.
- Special attention should to be paid to sectors that bring immediate benefits to the economy. In that regard, the needs of ICI dependent customer service enterprises such as call centers are important. Leased line access is critical for these businesses.
- Facilitating e-business, e-business in export industries in particular, is also important. Affordable broadband access and availability of secure servers are important for the conduct of e-business.
- Device to device communications containing location, environmental and identity data will be important in the long run but the utility of these technologies is yet to be demonstrated.

4. FACTORS AFFECTING S&T INPUTS TO ICI DEVELOPMENT

The existing ICI is a result of investments made by multiple ICI service providers including the former government monopoly now an independent company. The present ICI consists of fixed and mobile telephone networks and dedicated data links. The operators in the Sri Lanka telecom sector have acquired technical inputs such as switches and the connections through trade, with little product innovation. According to the former Director of the Arthur C. Clarke Institute for Modern Technologies (ACCIMT):

"All major telecom equipment including subscriber premises equipment is purchased from foreign manufacturers. The telecommunications industry being extremely competitive..... is reluctant to devote time and funds for local R&D. These organizations prefer quick solution procurement from abroad to keep ahead of the competition" [9].

The upside of this phenomenon is that in the short run Sri Lanka telecom providers are building an ICI in the most economic fashion. As a result, Sri Lanka has a relatively modern, though not necessarily low-cost, network infrastructure, and Sri Lankan customers are given the opportunity

to use cutting-edge technologies, at least in the mobile sector. Providing basic telephone services is the first step. The more challenging task is to develop the basic telephone networks and dedicated data links into an information and communication network that facilitates e-commerce, e-government, and e-society activities that create jobs, facilitate good governance, and empower the citizenry to pursue their individual goals and desires.

The backbone capacity, access technologies, peripheral devices, and enabling technologies used in ICI development continue to evolve at a rapid rate in the developed world. All ICI technologies except enabling technologies mostly encompass 'hard' technologies such as fiber and switches. Enabling technologies are mostly software-based. ICI providers, in Sri Lanka or elsewhere, cannot be expected to be leaders in manufacture of the hardware or the development of the software associated with these technologies. However, to function effectively as service providers they need to be able to pull together available access technologies, peripheral devices, and enabling technologies to provide the best service to the users.

What factors impede the local service providers from working with users, businesses in particular, to provide innovative ICI solutions using S&T inputs? What steps would remove the impediments? We will discuss several factors in the next few subsections. We include some non-S&T factors in order to put the S&T factors in context.

4.1. Lack of Demand

On the demand side, it is possible that there is no significant demand (not simply wanting the service but also willing to pay for what it costs) for ICI services. This explanation is unlikely in the case of business customers, given Sri Lanka's highly globalized industrial and agricultural sectors. The question of whether a substantial number of residential customers are capable of and are also willing to pay for broadband services in light of the relatively low levels of purchasing power caused by low wages and productivity is an open one. The only way it can be conclusively answered is by a process of market discovery - firms offering various configurations of services and not finding enough takers.

4.2. Government Inaction

Government inaction in regulation could be another reason. The effect of exercise of market power by dominant firms can be subsumed under this heading because in the end the government is responsible for such actions, either through allowing or encouraging anti-competitive behavior, especially by government-owned incumbents, or by inaction in not preventing such actions. The granting of an ambiguous exclusivity over international telephone services for five years to Sri Lanka Telecom Limited at the time of its partial privatization in 1997, the failure to effectively enforce the Telecommunications Regulatory Commission's interconnection determination of 1998 and the efforts of the TRC to harass SLTL's competitors in order to enforce its ambiguous exclusivity in 2000-2001 fall within the scope of government action/inaction that was responsible for inadequate levels of innovation in ICI-based services. Given this report's focus on S&T inputs as opposed to policy or regulatory actions, it is not necessary to expand upon the contributions of government, except to emphasize the need to create a policy and regulatory environment that is conducive to innovation by telecom service suppliers.

4.3. Information Gaps

All markets are affected by information problems; some more than others. It is possible that businesses are not aware of what IT enabled services and telecom services can do for them and that ICI service providers do not know what their customers really want. Even if they do, it is possible that the employees of the service supplier are not equipped to respond in innovative ways. Government action to improve the information supply regarding new ICI services and how they can benefit industries, agricultural firms and so on is likely to be beneficial. Yet this action does not fall clearly within the scope of an S&T input.

4.4. Lack of an Innovation Culture

Providing ICI services, by their very nature, require a relationship between supplier and customer and even a degree of customization. Local service suppliers would have an edge over their foreign competitors in maintaining satisfactory relations with their customers and in providing services that would meet their unique requirements. Effective service supply would necessarily require adaptation of externally obtained technology inputs. Under competitive conditions such as those that prevail in Sri Lanka, the service suppliers would also have to pay significant attention to lowering the costs of their inputs in order to enable the offering of low prices and high quality. This too would require intelligent purchasing of technology inputs and adaptation.

The existence of relatively sophisticated firms in Sri Lanka, many with international exposure either in terms of foreign direct investment, managerial inputs, or trading relationships, suggests that the high-end of the telecom services market does not suffer from a lack of information about what telecom services they require. The overall corporate culture of Sri Lanka being somewhat backward, it is possible that the ICI service suppliers have difficulty in understanding what their customers want and responding innovatively to customer demands.

What kind of employee is needed in an ICT service provider when continuing innovation is necessary on the part of service suppliers and their employees? Instead of buying what everyone else is buying they seek to buy what is appropriate for their customers' specific needs. What they buy, they combine in novel and unusual ways to both meet the unique requirements of their customers and reduce costs. They do not rest content with the way things have been done, but continually seek to improve the services provided. These actions require a different kind of employee.

The ideal employee would learn problem-solving skills from an early age, rather than memorize masses of facts to be regurgitated at periodically held examinations. Most of these facts, especially in rapidly changing fields such as are under discussion, are obsolete at the time of regurgitation if not before. The ideal employee would learn to learn. This includes sophisticated information gathering, parsing and discriminating skills. Much of the information that is relevant to innovation in the ICI exists, not in textbooks, but in databases and on the Internet. The difficulty is not that there is a dearth of information, but that there is too much, not all of it of equal quality, reliability and value. The ideal employee would be able to separate the wheat from the chaff, not perfectly, but adequately. The types of information that are relevant to innovation in the ICI are not necessarily written in lay language. The discriminating searcher would have to be literate in the technical field. In addition, he or she would supplement that literacy through continuing professional education, not resting upon one's undergraduate education as is customary in Sri Lanka (except where foreign travel and additional certificates are involved). Finally, the ideal employee would be able to function well in teams and network with colleagues. Teamwork allows for the development of well-rounded innovations. Networking enables the gathering of tacit or unpublished knowledge and the identification of short cuts in the process of information gathering. Both require empathy or what is known as emotional intelligence [10].

Most of the professionals who work in firms that supply telecom services are university graduates with S&T backgrounds. Their poor performance as employees can be laid squarely on the poor quality of Sri Lankan education. A shift away from rote-based learning that emphasizes retrieval of facts toward a problem-solving model of education would be of significant benefit for enhancing innovation in the ICI. Improving the empathic and problem solving skills of students in these disciplines will not only make a contribution to a better ICI, but to the overall dynamism of the economy.

4.5. Lack of S&T Capacity

Industry acquires technology through trade, direct foreign investments, licensing, recruitment of skilled personnel or in-house R&D. Do Sri Lankan industries or public institutions have the capacity to harness external S&T inputs or create domestic S&T inputs for ICI development? There are several indicators of the capacity of a country to develop technology or harness existing technology for development, some indicators more reliable than others. We will use some of those indicators to argue that in Sri Lanka neither the private sector nor the public sector currently has the capacity to innovate except perhaps in the area of 'soft' S&T inputs.

4.5.1. Capacity in the Private Sector

The ratio of medium to high technology exports to all exports is used as an indicator of how well a country uses technology in development. Sri Lanka ranks way below Malaysia or Thailand in medium to high tech exports (Malaysia, 67.4%; Thailand, 48.9%; Sri Lanka, 5.2%). Medium to high technology export data capture a broad range of 'hard' technology exports such as machinery and ICT equipment such as computers, audio and video devices. The enabling technologies component of an ICI is largely software based. Pulling together the access and peripheral technologies of an ICI also require software inputs. Data on software capabilities are not available through international statistical sources. According to the Board of Investment (BOI), Sri Lanka is currently where India was 10 year ago in terms of software development. In the ICT world ten years can be lifetime but ICT is thought to be an area where latecomers may have a good chance of catching up. S&T inputs to the 'soft' side of ICI development are possibly an area where Sri Lanka may have potential.

The extent of industry participation in R&D is another measure. The importance of private sector R&D to development is highly underestimated. In developed countries, the bulk of R&D is performed by industry. For example, in 1998, the US industry R&D accounted for 66% of all national R&D expenditure [11]. In newly industrializing countries, the rate of industrialization is marked by an increasing share of industry contributions to the national R&D expenditures. Korea and more recently Malaysia are two countries that have significantly increased their high technology exports in recent times. (India too belongs in this category and is probably a better example to use in regard to ICT exports but data from India are difficult to interpret because of the large size of the country and the existence of wide disparities within the country). Both Korea and Malaysia demonstrated a higher share of industry participation in domestic research as the level of industrialization grew in each country. For example, in Korea, industry's share of national R&D grew from 10% to 80% from 1978 to 1998. A similar pattern is observed for Malaysia. From 1992 to 1998, the contribution of Malaysian industries to national R&D grew from 45% to 66% (data prior to 1992 are not available). According to Sri Lanka NSF sources, industry R&D expenditures account for only 1.5% of total national R&D expenditures (The 'general services' sector performs 74.5% of the R&D and the universities account for 24.5%).

By either indicator, high technology exports or industry share of R&D expenditures, it is clear that Sri Lankan industries currently do not have the capacity to use S&T inputs for ICI development except in the case of software development industries.

4.5.2. Capacity in the Public Sector

There are no reliable international statistics to gauge the availability and the quality of S&T resources in the public sector. The research expenditure data and research personnel are fraught with problems because different countries may use different standards to report the data. The best available international assessment of university research capacity is the 'Best Universities in Asia' Survey carried out by the Asia Week magazine. The best known survey of this type is the US News and World Report's ranking of universities in the US. US News rankings have improved over the years and these rankings are widely used by institutions to gauge their performance relative their peers or aspirational peers. The Asia Week survey is relatively new but the results of the survey can be used as a rough guide to assessing the status of Sri Lankan universities relative to their Asian counterparts.

Asia Week surveyed 77 institutions in Australia, Bangladesh, China, Hong Kong, India, Indonesia, Japan, Malaysia, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, and Thailand. The University of Colombo is the only Sri Lankan institution ranked in the survey and that institution was ranked 77. India had ten institutions ranked with 8 of them in S&T category and two in the multidisciplinary category; five of the schools of science and technology ranked in the top 10. Malaysia had 4 institutions ranked (three multidisciplinary two S&T) with one S&T institution placed in the top 50%. Thailand had 10 institutions ranked (5 multidisciplinary and 5 S&T) with all 5 S&T institutions ranking in the in the top 50%.

There are 13 universities and several post-graduate institutes in Sri Lanka with pockets of research excellence located in some or all of these institutions, but clearly, none of the institutions can be considered research universities. It is not clear whether the sum of all pockets of excellence would be the equivalent of major research university. In this networked age, any discussion on S&T inputs to developments through universities would be meaningless without the presence of research base that is of high caliber by international standards. The NSF of Sri Lanka does a fairly good job of tabulating

S&T indicator data. In fact, the SL-NSF is one of the few national institutes in Asia that makes a comprehensive set of indicator data available in the public domain. NSF's work should be extended to provide a comprehensive analysis of the S&T capacity of public institutions in the country in relation to set of benchmark institutions from outside of the country.

5. DEVELOPING OR HARNESSING S&T INPUTS

How would a developing country develop or harness S&T inputs for ICI development? We will look at four modes of developing or harnessing S&T inputs - foreign direct investments, clusters of innovation, university-industry partnerships and enlisting the support of the S&T diaspora

5.1 Direct Foreign Investments

Development of high technology manufacturing in emerging economies such as those in Korea and Malaysia is largely attributed to the success of attracting and using Foreign Direct Investments (FDI) from Trans National Corporations (TNCs). For example, Korea's emergence as a major exporter of high technology products is largely attributed to the foreign direct investments, which brought turnkey operations to the country.

During the last three decades the Korean economy had made remarkable progress. This is due to many factors including the import of technical know-how from overseas. Some people might take it as being due to successful engineering, technical education and research. But it may not be correct in some sense. Many established industries during 1960's-70's in Korea were being run with the support of advanced countries. In other words, it was simply an introduction of the turnkey base engineering system from overseas [12].

Trade, FDI, and licensing will continue to be sources of S&T inputs to development. According to data compiled by Malaysian Science and Technology Information Center (MASTIC), R&D expenditure in Malaysia incurred by foreign companies accounted for 40% of the RM 746 million worth of R&D carried out in that country in 1998. Data for prior years are not available but anecdotal data suggests that foreign companies carried out a bulk of the R&D in prior years with local industries increasing their contribution over the years. How Malaysian industries increased their domestic R&D capacity is worth studying further, but in the meantime we can rely on other evidence that points to the importance of enhancing 'absorptive capacity' of host countries—the most important capacity being availability human capital resources [13].

5.2 Clusters of innovation

The cluster concept of innovation is another mode of S&T inputs to development. A cluster, as defined by Michael Porter of Harvard University, is a geographic concentration of competing and cooperating companies, suppliers, service providers, and associated institutions that arise out of linkages or externalities across industries. The associated institutions would be universities and research institutions that are drivers of R&D. In Sri Lanka it would be meaningless to expect universities to be drivers of innovation in R&D when they do not have the R&D capacity or the support needed to develop the capacity. Concepts of innovation such as cluster formation are often used in developing countries without a critical evaluation of the capacity of these countries to implement these concepts. The government might facilitate the clustering of competing and co-operating organizations if there is evidence of emerging competition and cooperation among organizations.

5.3 University-Industry Partnerships

Another potential source of innovation in industry is public–private partnerships. Here too the lessons from the developed world cannot or should not be applied directly to developing country situations. We presented some data to show that the private sector and the public sector currently may not have the capacity to innovate. Further work needs to be done in this area to identify strengths and means of building on existing strengths before imposing unrealistic expectations on universities and the few research faculty in these institutions. We propose that the government take the lead in

developing information sources that benchmark the performance of the public sector institutions in relation to selected institutions in other Asian countries, and make a realistic assessment of the S&T capabilities of public sector institutions in Sri Lanka.

Even in the developed world where both the private and public sector research bases are strong, the success of formal public-private alliances is debatable. More successful are deregulatory policies such as the Bayh-Dole Act where by public institutions were allowed to commercialize products of research funded by government and liberal policies by public sector institutions that provided incentives to researchers for entrepreneurial activities. Increases in patenting and licensing activities by universities and the growth of companies spun off by university faculty are largely attributed to these liberalization policies. Therefore we also propose that government liberalize policies regarding public-private partnerships to foster such partnerships in cases where strengths in research in the university and the needs of the local industry coincide.

5.4 S&T Diaspora

The Sri Lankan diaspora, or Sri Lankan nationals who live abroad, with advanced training in S&T is a clear source of potential inputs to ICI development. The Board of Investment has initiated a major back-to-Lanka project aimed at potential investors in the Sri Lankan diaspora. Given the developments in communication technologies the expatriate nationals do not necessarily have to relocate to Sri Lanka. Given that the quality of life in developing countries and other factors may inhibit the return of the S&T diaspora, a mostly virtual form of participation may have to be explored [14].

5.5 Other

Some argue for increased funding of industry research through national funding agencies such as the Sri Lanka NSF and channeling funding provided through international agencies. These suggestions have to be evaluated carefully.

6. CONCLUDING REMARKS AND RECOMMENDATIONS

The United States is the world leader in ICI, having invented the Internet and most of what goes with it. The Nordic countries also have admirable achievements in ICI. In Asia, Japan has a sophisticated ICI, being a producer of ICI inputs, but has recently been overtaken by South Korea in a key indicator of ICI, broadband connectivity. Among countries of similar economic standing, India, particularly South India, has made immense strides in ICI development.

In general, the lesson that can be learned from the US and India is that the ICI flourishes when government takes its heavy hand off and allows multiple actors to participate in the process of building the ICI. Had the US government not had the courage to loosen AT&T's all enveloping hold on the ICI in a long process that stretched from the 1960s to the 1980s, it is certain that the development of the Internet and associated innovations would have been slowed by decades, at least. The tremendous advances made by Indian entrepreneurs in IT enabled services in the past decade were made without the government's involvement or assistance, and bypassing the existing bottleneck of the government telecom monopoly.

In opposition, one could always cite the Nordic countries and South Korea. These countries achieved great things in ICI with strong government involvement and without too much participation by multiple actors. It is theoretically possible that the Sri Lankan government could follow the Korean path. But it is practically impossible because the government is more or less bankrupt and unable to conduct basic government business due to inefficiency and corruption. For over a century the government supplied telecom services in Sri Lanka. There were enormous waiting lists (average of 10 years) while only 65 percent of switching capacity was used year after year; corruption; and atrocious quality of service. It was only after competition was introduced and the government monopoly was partially privatized that a semblance of good performance was achieved. It seems that the only realistic choice for the Sri Lankan government is to step back from ICI provision and assume the role of market facilitator.

6.1 Possible actions for the government

6.1.1. Provide the regulatory and legal environment and create incentives for innovation

(a) Government should ensure that the policy and regulatory environment is conducive to private investment; that barriers to entry are minimized; and that the conditions for the optimal participation of multiple actors in the ICI are maintained.

(b) Create incentives for innovation in all sectors.

Public Sector:

- Provide financial incentives for innovation. Allow public institutions and individual researchers to profit from their labour through collaboration with the private sector.
- Facilitate further clustering among research groups and private sector organizations if there is evidence of emerging cooperation among these groups.
- Develop mechanisms for evaluating the performance of public institutions in R&D relative to peer institutions in other Asian countries. Consider privatization of government research institutions that do not show promise of reaching the performance of benchmark institutions in their class.

Private Sector:

- Continue policies to foster FDIs and improve the climate for domestic R&D activities by Multinational Companies.
- Provide incentives to collaborate with public sector researchers and hire interns from S&E undergraduate and graduate population.
- Facilitate the clustering of competing and cooperating organizations, both private and public if there is evidence of emerging competition and cooperation.

6.1.2 Facilitate an innovation-culture in S&T education

ICI Technologies will arrive on the market at a fast and furious pace. The most important S&T input to ICI development is an S&T workforce that is able to keep an eye on new developments and select, adapt and innovate with new technologies to optimize e-business, e-government and e-society. We propose two sets of recommendations here. (Providing a comprehensive set of recommendations on this subject is beyond the scope of this paper.)

(a) Identify modes of private education as practiced in other countries, publicize the information in order to foster a public debate on the subject.

(b) Provide incentives for the private sector and the universities to collaborate on improving undergraduate education in S&E.

Additional resources are not needed for either of two proposals here. A major World Bank Project aimed at improving higher education is currently underway in Sri Lanka. Government should ensure that the coordinating entity for the World Bank Project on higher education makes the maximum use of these external resources.

6.1.3. Fill Information Gaps

(a) Consumers of ICI services may not be aware of new technological solutions available to them. The best mechanism for would be to facilitate the entrance of variety of service providers to the ICI service provider field. For example, the supply of decent service by the new entrants to the fixed access market did more to educate the public about what they should expect from the incumbent, than ten information campaigns.

(b) Provide periodic assessment of the S&T capabilities of the public and private institutions as they relate to development. Sri Lanka NSF has made a good start with current set of S&T indicators data made available in the public domain. To make the S&T indicators more meaningful, the NSF analysis should include comparisons with selected peer countries (or aspirational peer countries) in Asia and elsewhere. Analysis by MASTIC or Science indicators developed by the US-NSF may serve as exemplars. The analysis should be used to set priorities in funding of public sector research and facilitating public-private partnerships.

REFERENCES

[1] Global Information Technology Report (GITR), Center for International Development, Harvard University, 2002

[2] Mansell, Robin and Uta Wehn (1998). *Knowledge Societies: Information Technology for Sustainable Development*. Oxford: Oxford University Press

[3] Melody, William (2000). Denmark Report, Delft, Netherlands: LIRNE.

[4] Tristram, Claire (2002). Handhelds of tomorrow, *MIT's Magazine of innovation: Technology Review*, Volume 105, No 3, April, pp.3442.

[5] Gage, John (2002). Some thoughts on how ICTS could really change the world, In Global Information Technology Report (GITR), Center for International Development, Harvard University, 2002

[6] Colony, George, Navi Radjou and Eroica Howard (2002). The X Internet: Leveling the playing field for businesses in the developing nations In Kirkman *et al*. (2002).

[7] Ntoko, Alexander. E-Business: A technology strategy for developing countries, ITU http://www.itu.int/ITU-D/e-strategy/publications-articles/wmrcjune00/ntoko.html.

[8] Kirkman, Geoffrey S., Peter K. Cornelius, Jeffrey D. Sachs and Klaus Schwab. (2002). *The Global Information Technology Report 2001–2002: Readiness for the Networked World*, Center for International Development, Harvard University, Boston, Massachusetts. p.80

[9] Kularatne, Nihal (2000), Contribution of Science and Technology to the electronics, communications and IT sectors of Sri Lanka, BICOST paper.

[10] Goleman, Daniel (1997). *Emotional Intelligence*. London: Bantam Books.

[11] National Science Board, Science and Engineering Indicators – 2000 (NSB-00-1). Arlington, VA: National Science Foundation.

[12] Ko, Myoung Sam (1996). The Symposium on Strategies for Academia-Government-Industry Partnerships Towards the 21st Century -Science and Industry in the Network Society, Nara Institute of Science and Technology and the Ministry of Education of Japan, November 28-29.

[13] Saggi, Kamal (2000). Trade, foreign Investment, and International Technology Transfger:urvey, a background paper for the World Bank 's "Microfoundations of International Technology Diffusion" research project.

[14] Teferra, Damtew (2000). Revisiting the Brain Mobility Doctrine in the Information Age. A paper presented at the Regional Conference on Brain Drain and Capacity Building in Africa. 22-24 February 2000, Addis Ababa, Ethiopia.