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A Framework for Assessing the Global Diffusion of the Internet

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Abstract

This paper presents a comprehensive framework for describing the diffusion of the Internet in a country. It incorporates insights gained from in-depth studies of about 25 countries undertaken since 1997. The framework characterizes diffusion using six dimensions, defining them in detail, and examines how the six dimensions relate to underlying bodies of theory from the national systems of innovation and diffusion of innovations approaches. It addresses how to apply the framework in practice, highlighting Internet diffusion determinants. This framework is useful for business stakeholders wanting to make use of and invest in the Internet, for policy makers debating how to positively (or negatively) influence its use and development, and for researchers studying the large-scale diffusion of complex, interrelated technologies.

Keywords: Internet, WWW, diffusion, technology cluster, country, framework, measurement, innovation.

I. INTRODUCTION

With a jump in the user base from tens of thousands at the beginning of the 1990s to over 300 million at the end, the Internet has undoubtedly diffused faster than almost any other technical innovation in modern times. And yet, trying to characterize the nature of this diffusion beyond some obvious, first order statistics such as number of hosts, is exceedingly difficult. Even the definition of what constitutes a true "user" or host is difficult to pin down. How any given user experiences the Internet depends on a wide variety of factors. The Internet topology is constantly changing and is a delivery mechanism for a constantly evolving array of software applications and information. At the same time, numerous Internet "factoids," such as November 2000 estimate of 407 million Internet users, are constantly being introduced by a barrage of press releases and web sites [Nua Internet Surveys 2001]. The underlying methodologies for these studies are often obscure. This leads both to confusion and to a false sense that we know what is going on.

The purpose of this paper is to set forth a framework by which Internet diffusion may be measured at the national level. This framework was developed by the MOSAIC Group as part of the Global Diffusion of the Internet Project (GDI). Parts of it have been explained in previous papers [Goodman et al. 1998b; Press et al. 1998] or in studies of specific countries, but this is the first time it is being published in full. The framework is based on an on-going inductive study of the Internet in a wide representation of countries around the world.[1] This paper does not try to set forth a general theory of why the Internet diffuses as it does, but may be considered a necessary precursor to the development of such a theory.

The need for well-justified country-level diffusion metrics is strong. The recent proliferation of various "e-readiness" and similar indexes, and a recently announced initiative by the World Bank's Information for Development Program to fund such studies [Infodev 2001], underscores the strong interest of policy makers and business people alike. Researchers who are studying how the Internet is influencing and changing the economic, political, and social systems of various countries have been limited by the absence of measures that are more accurate, descriptive, and sophisticated than the simple number of Internet hosts in a country [Menou 1999; Wilson et al. 1998].

Interest in national level metrics is well-founded. Miller and Slater [2000, pg. 1], in justifying their ethnographic approach, point out that, "contrary to the first generation of Internet literature—the Internet is not a monolithic or placeless 'cyberspace'; rather, it is numerous new technologies, used by diverse people, in diverse real-world locations." To *what* a user has access and *why* depends on the specific legal, economic, political, and social conditions that surround that user. In spite of claims that the Internet and other trends related to globalization are subverting the sovereignty of national governments and blurring national boundaries, governments still make policies that can have a dramatic effect on the diffusion and

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[1] Goodman et al. [1994] took an early look at Internet diffusion. See Table 11, section IV, for a list of GDI studies and references. Check Wolcott [2001] for new GDI work.

absorption of the Internet [Greenberg and Goodman 1996]. Furthermore, users are located within a particular national system of innovation, which also strongly influences the diffusion process and the absorptive capacity of a country.[2]

Authors who write papers that are primarily concerned with metrics always face a dilemma. If we begin by examining prior work and the theory behind the measures, we must ask readers to accept the justification without fully understanding the measures. If we put the measures first, we must ask the reader to temporarily accept that they do, in fact, have sufficiently strong justifications. We have chosen to present the measures first in section II, referring only to aspects of justification that are essential in directly describing the measures.

Classification systems reduce more complex phenomena to simpler representations that are easier to understand and to manipulate in the formulation and testing of hypotheses. Classification systems should be "natural," meaning that they represent real underlying properties and relationships—the way the world actually works [Ridley 1986]. They also should be practical, based on data that can be collected with reasonable accuracy, timeliness, and cost. We accordingly break the justification section into two parts. Section III concerns underlying theories and other work on Internet diffusion. We will consider the relationship of the GDI methodology to the national systems of innovation work, to evolutionary analogies, and to diffusion of innovations theory. Section IV concerns how the framework may be applied in practice, and presents a brief summary of one of the GDI studies. Section V presents conclusions, contributions, and directions for future research.

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[2]Archibugi et al. [1999] and Edquist [1997] provide excellent introductions to the national systems of innovation (NSI) literature. The GDI methodology can also be applied to a region larger than a country or to sub-units within a country, and throughout this paper readers may substitute region for country with no loss of generality. This is in keeping with similar extensions to the NSI approach [Howells 1999]. We return to the NSI approach in section III.

II. A FRAMEWORK FOR ANALYZING INTERNET DIFFUSION WITHIN A COUNTRY

Traditional diffusion studies typically stop at the point at which a user has chosen to adopt a single innovation, and thus have a single dependent variable [Rogers 1995]. For the Internet, this variable has often been “number of hosts” or users. We will argue, however, that the Internet is not a single innovation but is a cluster of related technologies that must be present together to support adoption decisions by end users. The Internet cannot work unless there are servers, communication links, software, end user devices, content to transmit, etc. For interactive technologies such as the Internet, network externalities influence the critical mass needed for widespread adoption [Mahler and Rogers 1999]. Using a single measurement variable does not capture the richness of what is happening and in fact may be misleading.

The GDI framework, therefore, consists of six *dimensions,* each of which describes an important, somewhat intuitive, and measurable feature of the presence of the Internet in a country. In a rough sense, these dimensions form a complete set in that they collectively cover most things that might reasonably be of interest, and each dimension offers something to the overall picture that the others do not. They have been chosen to reflect the full cluster of constituent technologies from infrastructure to end user applications, thus capturing the multifaceted diversity of experiences that countries have with the Internet. At the same time, the number of dimensions is small enough that they can easily be kept in mind. The values assigned to each dimension are discrete and proceed from less to more in an ordered way. Each discrete level maps to a relatively broad range of underlying values or conditions, a breadth that is sufficient to reflect the fact that much of the information available about the Internet changes rapidly, is incomplete, and varies in credibility. The conciseness of the dimension definitions should allow different people looking at the same raw data to assign the same values to them.

The framework also includes *determinants,* which may be thought of as proximate causes that led to the current conditions. Understanding how the determinants influence the dimensions in a given country can lead to prescriptive statements, and GDI studies typically include thorough analyses of both the dimensions and the determinants [cf. Wolcott and Goodman 2000]. While the determinants are discussed to a certain extent in sections III and IV, the focus of this paper is on the dimensions.

The results are presented on a Kiviat Diagram [cf. Kolence and Kiviat 1973] with six "spokes" representing each of the dimensions. Values for one or more countries at one or more times can be plotted on the same diagram or compared side-by-side on several diagrams. Figure 1, for example, shows the status of Internet diffusion in Turkey and Pakistan in 1999. Figure 2 shows the rapid growth of the Internet in Finland from 1994 to 1997.

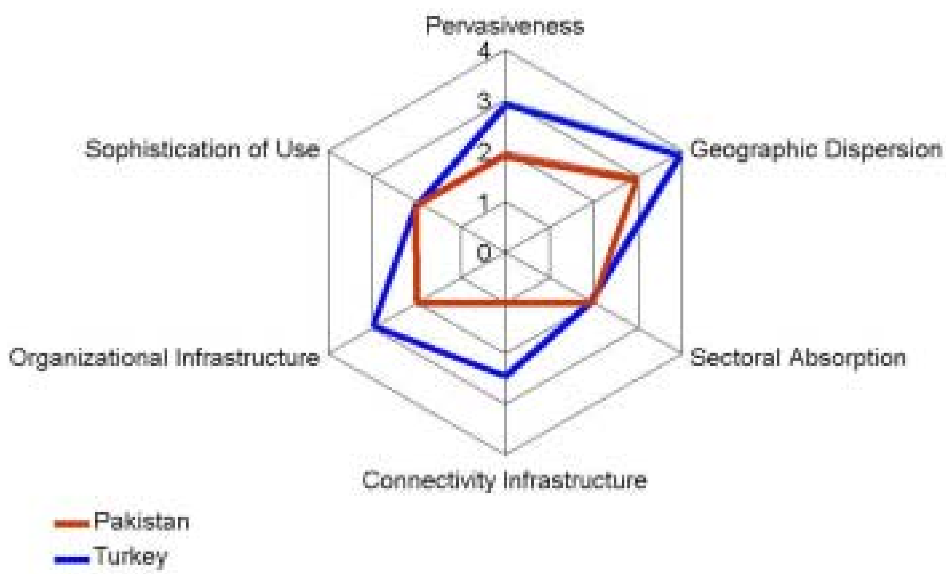

Figure 1. Dimensions for Turkey and Pakistan, 1999

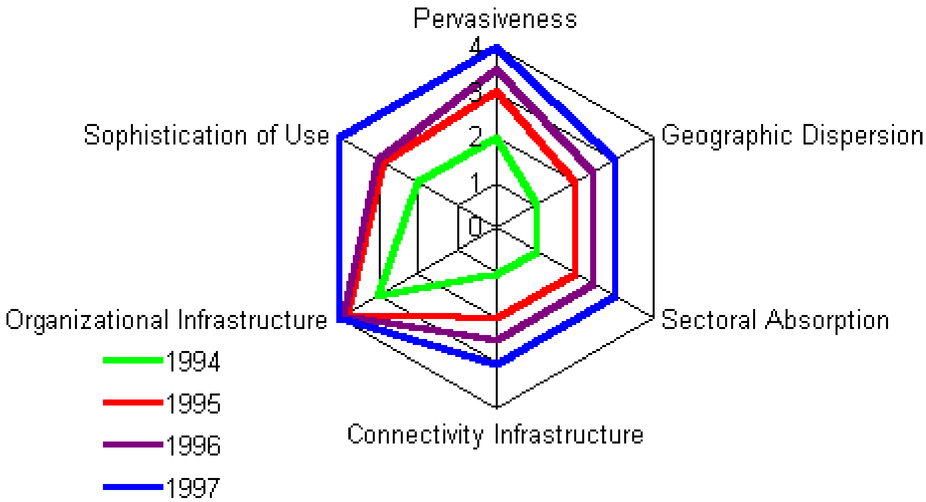

Figure 2. Dimensions for Finland, 1994-1997

The dimensions and determinants and their intervals were developed by a team of six members of the MOSAIC Group, including most of the authors, with expertise about the Internet in a wide variety of countries including the United States, China, Finland, Chile, Cuba, the Gulf States, and India. We have since applied the framework to Internet diffusion in about 25 countries (see Table 11 in section IV). Although we have made a few modifications in the framework based on accumulated experience, we have found it to be an excellent tool for analyzing the Internet in each of these countries. In the rest of this section, we first examine the nature of the Internet technology cluster and how this led to the selection of the dimensions, and then we present the dimensions in complete detail. In section III, we return to the more theoretical questions of why these dimensions should depict Internet diffusion and other work that has been done along these lines.

FRAMEWORK DIMENSIONS: OVERVIEW OF THE CLUSTER

A simple model of the Internet technology cluster depicts three levels (Figure 3).[3] At the bottom level is the underlying network infrastructure, without which there can be no Internet in practice. We have created a corresponding dimension called "*Connectivity Infrastructure*." At the top level are the technologies needed by end users in order to adopt and make use of the Internet. We have chosen to depict this level with two dimensions. *Pervasiveness* is an overall measure that reflects the raw number of individual Internet users in a country. *Sectoral Absorption,* on the other hand, considers Internet use from the viewpoint of adoption at an organizational level.

Next, there has to be some sort of mechanism to bring services from the telecommunications infrastructure to the users. We have depicted this Internet services infrastructure layer in two dimensions. The first, *Organizational Infrastructure,* is primarily focused on the number and robustness of the organizations that provide these services. The second, *Geographic Dispersion,* reflects the extent to which these organizations, along with the supporting telecommunications infrastructure, is distributed across the entire territory of a country.

Both the pervasiveness and sectoral absorption measures are similar to the constructs of traditional diffusion studies in that they simply consider whether or not the technology has been adopted, and do not try to distinguish among various intensities of adoption or various uses. A third user-oriented dimension, therefore, is *Sophistication of Use,* which tries to plug this gap. It recognizes that the adoption of the leading edge applications depends not only on what the users want, but also on what the Internet services infrastructure is able and willing to provide. Figure 3 shows all six dimensions along with the single or multiple levels in the technology cluster to which they correspond. In the next section, we consider the definitions of the dimensions in complete detail.

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[3] A much more complete map of the information industries is provided by Houghton [1999], who defines 16 segments divided on the horizontal axis by conduits to content (form to substance), and on the vertical axis by products to services.

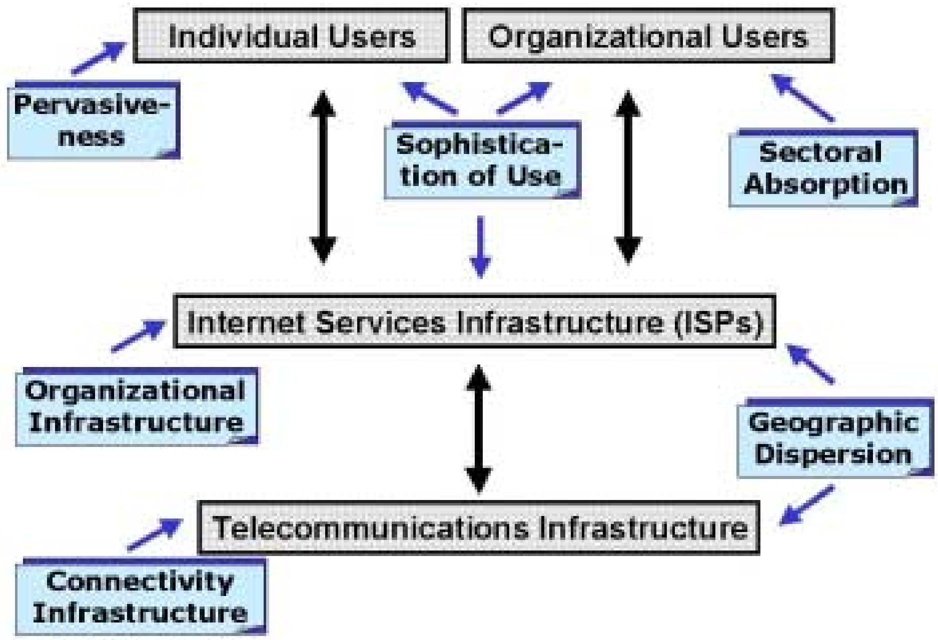

Figure 3. Constituents of the Internet Technology Cluster

FRAMEWORK DIMENSIONS: DEFINED IN DETAIL

Pervasiveness

Pervasiveness (Table 1) is a function principally of the number of users per capita. It differs from commonly used Internet growth metrics only in that the final measure of Pervasiveness is not an absolute number, but a ranking of that number in one of five levels. The intent is to depict the portion of a population that uses the Internet.[4] Accurate user counts are not readily available. However, it is often possible to obtain or reasonably estimate the number of users accessing the Internet through switched (dial-up) and fixed (LAN) connections by extrapolating from numbers of subscribers. In some countries, one user may access the Internet in numerous ways (including wireless, Internet cafes and kiosks, and home, work and/or school accounts), while in others single accounts may be shared by many

[4]When data are available to do so, we exclude those who have only UUCP, Fido, or any store and forward accounts.

users. Some users are heavy and others light; some started long ago while others started recently. Estimates based on samples, therefore, may provide more accurate results when available, and the authors of GDI studies often discuss these subtleties when examining the evidence for assigning this parameter. Ultimately, reports on users usually are in the same order of magnitude, and therefore get the same rating under the GDI definitions.

Table 1. The Pervasiveness of the Internet

Level 0	*Non-existent*: The Internet does not exist in a viable form in this country. No computers with international IP connections are located within the country. There may be some Internet users in the country; however, they obtain a connection via an international telephone call to a foreign ISP.
Level 1	*Embryonic*: The ratio of users per capita is on the order of magnitude of less than one in a thousand (less than 0.1%).
Level 2	*Nascent*: The ratio of Internet users per capita is on the order of magnitude of at least one in a thousand (0.1% or greater).
Level 3	*Established*: The ratio of Internet users per capita is on the order of magnitude of at least one in a hundred (1% or greater).
Level 4	*Common*: The ratio of Internet users per capita is on the order of magnitude of at least one in 10 (10% or greater).

Traditional diffusion studies make no assumption about the total number of potential users, and typically divide the adopters into innovators (first 2.5%), early adopters (next 13.5%), early majority (next 34%), late majority (next 34%), and laggards (last 16%) [Rogers 1995, pp. 252ff]. The GDI framework uses a log-arithmic scale. Why?

In order to measure Internet diffusion in a country, which has a known population and therefore a known upper limit on the number of adopters, it only makes sense to measure against the country's population. A "per capita" scale allows comparisons among countries. The discrete logarithmic levels makes it possible to consider the very early stages in much greater detail than is revealed by the traditional adopter categories. We are interested in understanding at what point the Internet has "taken hold," as well as the point at which it has become common. Our scale provides for comparisons between developing and developed nations.

Geographic Dispersion

Geographic dispersion (Table 2) describes the physical dispersion of the Internet within a country. In addition to just having the network accessible throughout the country, there are benefits to having multiple points-of-presence within an area, redundant transmission paths, and multiple international access points. In many countries, the Internet has only been accessible in the capital city. Widespread geographic dispersion is a requirement for the Internet to transform the country as a whole and not just a few isolated cities.

Table 2. The Geographic Dispersion of the Internet

Level 0	*Non-existent*. The Internet does not exist in a viable form in this country. No computers with international IP connections are located within the country. A country may be using UUCP connections for e-mail and USENET.
Level 1	*Single location*: Internet points-of-presence are confined to one major population center.
Level 2	*Moderately dispersed*: Internet points-of-presence are located in multiple first-tier political subdivisions of the country.
Level 3	*Highly dispersed*: Internet points-of-presence are located in at least 50% of the first-tier political subdivisions of the country.
Level 4	*Nationwide*: Internet points-of-presence are located in essentially all first-tier political sub-divisions of the country. Rural access is publicly and commonly available.

Two problems typically arise in interpreting this dimension. First, the analyst must determine what counts as a "first-tier political subdivision." In most countries, the state, province, or governate constitutes the first-tier political subdivision. Some countries have a small number of large divisions, such as the Philippines' division into three main island groups of Luzon, Visayas, and Mindanao. In this case, using the next level division of the province makes more sense [Connally 2000].

Second, there is the question availability of dial-up access. Users obviously can get Internet access by making long distance calls, but usually the extra cost of doing so is prohibitive for all but occasional use. Effective rural access means, at the very least, that long distance charges need to be waived, and perhaps that unlimited local calls may be made for a single charge.

Sectoral Absorption

Sectoral absorption (Tables 3, 4, and 5) focuses on the extent to which organizations in four major sectors—academic, commercial, health, and public (government)[5]—have made a tangible commitment to Internet use. The subsectors describe the major social and economic divisions in society as depicted in Table 3. Personal use is not considered in this metric.

Table 3. Major Internet-using Sectors of the Economy

Sector	Subsectors
Academic	Primary and Secondary Education, University Education
Commercial	Distribution, Finance, Manufacturing, Retail, Service
Health	Hospitals, Clinics, Research Centers, Physicians/Practitioners
Public	Central Government, Regional and Local Governments, Public Companies

Internet use within each sector is rated as "non-existent," "minimal," "medium," or "great majority," using the guidelines in Table 4. To rate the country as a whole, each sector where there is no use of the Internet is assigned zero

[5]Health, commercial, and academic were initially selected because they corresponded to categories in the United Nations Development Programme (UNDP) human development index. The public sector is obviously a very important user, potentially comparable in size to the others. See **http://www.undp.org/**.

points, each minimal sector is assigned one point, each medium sector two points, and each great majority sector three points. These points are added together and then reduced to a single number using Table 5.

Table 4. Sectoral Use of the Internet

Sector	Minimal	Medium	Great Majority
Academic	> 0%–10% have leased-line Internet connectivity	> 10%–90% have leased-line Internet connectivity	> 90% have leased-line Internet connectivity
Commercial	> 0%–10% have Internet servers	> 10%–90% have Internet servers	> 90% have Internet servers
Health	> 0%–10% have leased-line Internet connectivity	> 10%–90% have leased-line Internet connectivity	> 90% have leased-line Internet connectivity
Public	> 0%–10% have Internet servers	> 10%–90% have Internet servers	> 90% have Internet servers

Table 5. The Sectoral Absorption of the Internet Scale

Sectoral point total	Sectoral Absorption dimension rating	
0	Level 0	*Non-existent*
1-3	Level 1	*Rare*
4-6	Level 2	*Moderate*
7-9	Level 3	*Common*
10-12	Level 4	*Widely used*

Sectoral absorption paints an important picture of how the Internet is perceived in different countries. In some, there may be considerable commercial use but little use in the public sector. In others, this pattern may be reversed. Typically the health sector is one of the last to adopt the Internet, so that rating a country at Level 4 is very indicative of widespread diffusion. We explicitly chose not to include non-governmental organizations, religious organizations, and other organizations (e.g., organized crime) that do not fall under these definitions either because they play a relatively small role in the economy or because information about them is even harder to obtain. In determining the ratings within each sector, we chose to map the medium value to a rather wide range of underlying conditions because we are interested in distinguishing the state where only innovators and some early adopters have embraced the Internet (on the order of 10%) from the state when even the late majority have adopted the innovation (on the order of 85% to 90%). Having such a wide definition increases the likelihood that different analysts will reach the same conclusions about the same or different countries, making it more robust when these data are difficult to obtain.

The presence of a server or use of a server co-hosted elsewhere represents a serious commitment by an organization to the Internet. Similarly, paying for leased lines indicates a considerable amount of use. We chose to focus on servers for commercial and public organizations, and leased lines for educational and health organizations, because these better represent the types of information flows in and out of these organizations, but they are both surrogates for indicating commitment to the Internet, and may be used interchangeably.

Connectivity Infrastructure

Connectivity infrastructure (Table 6) assesses the extent and robustness of the physical structure of the network, and comprises four components: the aggregate bandwidth of the domestic backbone(s), the aggregate bandwidth of the international IP links, the number and type of inter-connection exchanges, and the type and sophistication of local access methods being used. Table 6 depicts how these factors are related to the assessment of the level of infrastructure development, with Level 0 assigned to a country with no Internet presence (and hence, no infrastructure) and Level 4 assigned to a country with a robust domestic infrastructure, multiple high-speed international links, many bilateral ("peering") and open Internet exchanges—facilities where two or more IP networks exchange traffic—and multiple access methods in use.

Table 6. The Connectivity Infrastructure of the Internet

		Domestic Backbone	International Links	Internet Exchanges	Access Methods
Level 0	*Non-existent*	None	None	None	None
Level 1	*Thin*	≤ 2 Mbps	≤ 128 Kbps	None	Modem
Level 2	*Expanded*	> 2Mbps – 200 Mbps	>128 Mbps – 45 Mbps	1	Modem 64 Kbps leased lines
Level 3	*Broad*	> 200 Mbps –100 Gbps	> 45 Mbps – 10 Gbps	More than 1; Bilateral or Open	Modem > 64 Kbps leased lines
Level 4	*Extensive*	> 100 Gbps	> 10 Gbps	Many; both Bilateral and Open	< 90% modem > 64 Kbps leased lines

Estimating the aggregate capacity of both the domestic backbone and international links has been problematical. Some of the GDI authors have added together the capacity of all the lines found and called that the aggregate capacity, an approach similar to that taken by TeleGeography [Abramson 2000]. This approach is most attractive for international links, where it makes sense that each additional line going out of a country adds to the overall throughput of traffic that can flow in and out of the country at any given time. Such an aggregated measure, however, does not begin to answer the question of where the traffic needs to go and what are the costs associated with specific flows. TeleGeography reported that aggregate bandwidth from Africa to Europe (as of September 1999) was 68.5 Mbps, but Africa to the U.S. was 170 Mbps. Traffic may flow from Africa to the U.S. via Europe and vice versa, so is it really accurate to say that total bandwidth to the U.S.

is only 170 Mbps and not 238.5 Mbps? Nevertheless, major backbone providers have adopted this measure, and it seems to be a reasonable way to characterize countries. Wilson et al. [1998] use total bandwidth to outside countries.

Using such an approach for the domestic backbone is more problematical, because the patterns of connectivity among backbone components influence overall throughput and performance. Fiber-miles or fiber-kilometers are often used to describe capacity, but this does not capture the fact that different devices at either end will change the throughput of the fiber. Therefore, some researchers just focus on measured performance. The Center for International Development at Harvard focuses largely on the services provided from the end-user's point of view [Information Technologies Group 2000]. Boardwatch also focuses on end-user delivered performance, testing download times for files from various vantage points at various times [Martin 2001; Muellar and Erickson 1999]. Despite outlining a promising method for examining network capacity based on mathematical depictions of network connections as graphs,[6] Gorman and Malecki (2000, pg. 122) aggregate "the total bandwidth available to each network…to give a measure of the…gross capacity of each network." We have used this approach in most GDI studies. The levels that we have outlined in Table 6 refer to adding up the capacity of all the links in the backbone(s) in the country. Given the rapidly changing levels of capacity around the world, the thresholds in Table 6 need frequent scrutiny and revision.

Without domestic Internet exchange points, traffic from one ISP to another within the same country must first travel outside the country to a global connection point. Domestic Internet exchanges presumably reduce costs and increase speeds. The presence of such exchanges often indicates a certain level of maturity among backbone providers, and provision of ancillary services that facilitate the development of the Internet as a whole. Open exchanges allow any qualified backbone

[6]For each network, they derive the cyclomatic number and the alpha, beta, and gamma, which are all ratios derived using various formulas from the number of nodes and connections between nodes (edges) in a graph. This is the underlying structure that comprises a computer network. Gorman and Malecki [2000, pg. 120] provide more precise definitions.

provider to join, while bilateral connections may be private. Our cutoff point on this parameter is somewhat vague, leaving it to the analyst to distinguish the point at which more than one exchange becomes many.

The access methods column tracks two different forms of access. One is the "last mile" connections, mainly into homes, that have traditionally used modems but may now be adopting cable, xDSL, or even other forms of access (e.g., fixed wireless or satellite). These newer forms of access appear in our framework at level 4, where the rating of < 90% using modems assumes that the rest use one or more of these methods. The second form of access is via a leased line, and here we have made a distinction between those that are no greater than 64 Kbps (older ISDN technologies), and those that are. The higher speeds of cable, xDSL, and other methods may soon blur distinctions between slow, home access and fast, work access, although the rate of broadband adoption around the world has been much slower than expected.

Although it is possible to imagine a country in which one of these four constituents of the telecommunications infrastructure was at Level 4 and another at Level 1, our experience has shown that when the constituents diverge, they tend to cluster around two levels. Choosing a particular level depends on there being three out of four ratings on a particular level. When a country is clearly between levels, we have sometimes evaluated it as halfway between, but have generally stayed away from half ratings because this changes the framework from five levels to ten.

Organizational Infrastructure

The Internet services infrastructure is the "middleware" between the basic telecommunications infrastructure and users that makes the raw "pipes" useable. Our measure, organizational infrastructure (Table 7), is centered on the number of Internet Service Providers (ISPs) and their competitive environment. It tries to assess the robustness of the market and services themselves, and recognizes that when strong competition is present, more services will probably be offered. ISPs may be transforming themselves into Internet content providers (ICPs) and application service providers (ASPs), and the array of services offered at this level is expanding. Some countries will permit this evolution and some will not. The definition for Level 4 includes the concept that a group of ISPs has begun to gel as an industry, and is therefore creating mechanisms that will enhance its professional standing. Public exchanges signify that ISPs are working together. Collaborative organizations, such as industry associations, can lobby on behalf of the ISPs, ICPs, and ASPs. Emergency response teams cut across organizations and may require joint funding. These are examples, and other indications of robustness may be found in various countries.

Table 7. The Organizational Infrastructure of the Internet

Level 0	*None*: The Internet is not present in this country.
Level 1	*Single*: A single ISP has a monopoly in the Internet service provision market. This ISP is generally owned or significantly controlled by the government.
Level 2	*Controlled*: There are only a few ISPs and the market is closely controlled through high barriers to entry. All ISPs connect to the international Internet through a monopoly telecommunications service provider. The provision of domestic infrastructure is also a monopoly.
Level 3	*Competitive*: The Internet market is competitive. There are many ISPs and low barriers to market entry. The provision of international links is a monopoly, but the provision of domestic infrastructure is open to competition, or vice versa.
Level 4	*Robust*: There is a rich service provision infrastructure. There are many ISPs and low barriers to market entry. International links and domestic infrastructure are open to competition. There are collaborative organizations and arrangements such as public exchanges, industry associations, and emergency response teams.

Sophistication of Use

To truly understand the Internet capability of a country, it is necessary to understand not only how many people use the services and where, but also how the Internet is employed. As noted above, the Internet comprises a technology cluster, and various specific technologies are being adopted by different user groups at different rates. For example, one might study the demographics of the adoption of MP3 files for the distribution of music, or the diffusion of EDI-over-Internet use. Our measure (Table 8) attempts to synthesize sophistication in terms of what leading-edge groups of users are doing, while recognizing that to characterize a whole country by a small number of advanced users is not particularly useful. Part of the motivation of looking at leading edge groups is to see what is possible in a given social, political, and economic system; the trailblazers show that it can be done and lead the way for the others.

Table 8. The Sophistication of Use of the Internet

Level 0	*None*: The Internet is not used, except by a very small fraction of the population that logs into foreign services.
Level 1	*Minimal*: The user community struggles to employ the Internet in conventional, mainstream applications.
Level 2	*Conventional*: The user community changes established practices somewhat in response to or in order to accommodate the technology, but few established processes are changed dramatically. The Internet is used as a substitute or straightforward enhancement for an existing process (e.g., e-mail vs. post). This is the first level at which we can say that the Internet has "taken hold" in a country.
Level 3	*Transforming*: The use of the Internet by certain segments of users results in new applications, or significant changes in existing processes and practices, although these innovations may not necessarily stretch the boundaries of the technology's capabilities.
Level 4	*Innovating*: Segments of the user community are discriminating and highly demanding. These segments are regularly applying, or seeking to apply, the Internet in innovative ways that push the capabilities of the technology. They play a significant role in driving the state-of-the-art and have a mutually beneficial and synergistic relationship with developers.

Of particular interest is the point that is reached when the Internet attracts interest and use outside of a narrow community of technicians. Although there will be many “chasms” to cross for many sub-technologies [Moore and McKenna 1999], a country must first deal with adopting the basic services of the Internet. This is reflected in going from Level 1 to Level 2.

A second major milestone (Level 3) is reached when user communities integrate the Internet into business processes in such a way that significant changes are made in them. For example, the adoption of user-determined pricing mechanisms such as auctions may require substantial changes in the way a business operates. At an individual level, changing a business process may refer to shopping on-line, spending more time on-line than watching television, etc.

A third milestone is reached (Level 4) when user communities transition from only using the Internet to creating new applications, often eventually having an impact on the Internet elsewhere in the world. In the diffusion literature, this is called “re-invention” and has received only moderate attention from diffusion researchers [Rogers 1995, 174]. It can be argued that very few countries are in this category, with the United States being the leading example.

Table 8 depicts the development stages that reflect these increasing levels of sophistication in the use of the Internet. Not all users may ever reach the high water mark, especially with respect to Level 4, but knowing that a country is capable of being there is quite significant.

Table 9 illustrates some examples of usage of the Internet at various levels of sophistication by individuals and organizations at the time of this writing. This dimension is also subject to frequent scrutiny and possible revision, as yesterday’s innovations become today’s routine applications.

Table 9. Examples of Sophistication of Use of the Internet (circa 1999-2000)

Level	Individual Use	Organizational Use
Level 0 None	No use of the Internet	No use of the Internet
Level 1 Minimal	E-mail communication or Web browsing is an infrequent, and novel experience.	E-mail is available, but is not used as an alternative to traditional interpersonal communications (memos, telephone, meetings). Web sites consist of a very small number of static pages reflecting a "minimalist brochure."
Level 2 Conventional	E-mail may be a preferred means of communicating with people in an individual's circle of acquaintances. Web surfing is a regular activity. Some individuals maintain Web sites to post personal interest information. Individuals may listen to broadcast programming on the Web rather than on the radio or television. On-line Chat is an advanced form of Level 2, or possibly a Level 3, depending on whether it is primarily entertainment or results in changes in the individual's social network.	E-mail is widely used for both official and unofficial communication. Listservs or their equivalent are used to disseminate information or solicit feedback. Web sites are largely static, but are extensive and provide customers with in-depth information about products and services, utilization of those services, comparative information, etc. The content is more than just advertisement.
Level 3 Transforming	On-line communities proliferate around shared interests. These communities bring together people who otherwise would not have contact with each other. Interaction between members of such communities is substantive and often interactive. Examples include on-line Bridge clubs, use of ICQ ("I seek you") to create communities, Individuals' Web-cams (e.g., Jenni-Cam knock-offs).	One strong indicator of business process reengineering is that a significant number (over 5%) of Web sites, both government and business, are interactive. Web sites are dynamic, becoming an alternative distribution channel. On-line ordering is possible. Customer service functions expand to permit customers to conduct transactions that formerly involved employees (e.g., home banking, FedEx package tracking, etc.) International companies use the Internet as a substitute for business trips, enabling round-the-clock collaborative product development. E-Commerce/e-business has taken hold.
Level 4 Innovating	Highly sophisticated forms of technology supporting interpersonal interaction and access to content are not only used by, but developed for, a demanding customer base. Principal examples include the development (not just use) of highly-interactive on-line games, ICQ ("I seek you"), Napster, etc.	The fundamental structure of organizations and their external relations with other organizations is altered. Examples include Egghead Software, which no longer has a bricks-and-mortar presence, and Amazon.com, the on-line bookseller. Business-to-business (B2B) vertical exchanges continue to add more and more value as they integrate enterprise information systems.

III. INTERNET DIFFUSION: THEORY AND OTHER WORK

Any classification system has a strong relationship to the purpose for which it was conceived. To study Internet diffusion in a country, we first need measures that reflect the nature and actual adoption of the Internet. In section II, we have already satisfied the need to reflect the nature of the Internet by crafting measures that capture the underlying technology cluster that comprises it.[7] Pervasiveness and Sectoral Absorption are directly related to adoption, attempting to count numbers of things—like saying there are so many wolves in Alaska. They make use of the simplest possible characteristic: presence or absence.

If we were to stop with just these two adoption dimensions, we could say that we have captured diffusion within some geographical boundary, but we would be hard pressed to say that we have reflected the elements of a country in our analysis. The other four GDI dimensions are based implicitly on underlying theories of national systems of innovation, on evolutionary analogies (i.e., evolutionary economics), and on diffusion of innovations theory. The literatures on these subjects are vast, and it is beyond the scope of this paper to do justice to any of them. We can only make suggestive analogies and point to representative references.

The national systems of innovation (NSI) literature is primarily about how country- and region-specific institutions provide the necessary support for the development and diffusion of innovations within that country and/or region. Particularly over the last decade, this literature has examined key issues such as the role of multinational corporations in the development and diffusion of innova-

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[7] Van Slyke [1998] traces the concept of technology clusters to Silverman and Baily [1961], whereas LaRose and Hoag [1996] cite Rogers [1986] as the primary source. Technology clusters in information technology have been examined for a least a decade [cf. Chin and Moore 1991]. King et al. [1994] discuss clusters in the broader context of institutions and their role in innovation diffusion. Prescott and Van Slyke [1997] recommended treating the Internet as a cluster and summarize some evidence in support of this approach. Hahn and Schoch [1997] emphasize that a cluster entails adoption of some, but not necessarily all, of the constituent technologies.

tions and whether or not globalization is rendering the concept of the NSI obsolete. The overwhelming conclusion is that it is not [cf. Pavitt and Patel 1999].

Germane to our task is the kinds of measures the NSI approach uses. Patel and Pavitt [1994], for example, use multiple, complex measures such as dollar volume of research and development (R&D) activity by firms and by research and educational institutions; patents; published papers and citations to them; and census-based data on the population. These measures look both at inputs (e.g., the level of R&D investment), and outputs (e.g., the number of patents produced). Both are important: R&D investment stands as an indicator of the importance with which the nation views innovation, and the response of institutions to this challenge, but is also an input that may or may not produce new innovations. Complex measures such as these are justified because "innovations are generated not only by individuals, organizations, and institutions, but by their, often complex, patterns of interactions" [Saviotti 1997, pg. 180].

Connectivity infrastructure, organizational infrastructure, and geographic dispersion are similarly complex measures that incorporate both inputs and outputs and their interrelationships. Within this technology cluster (Figure 3), the amount of capacity and available services present in the bottom two levels determine the upper limit of the extent of Internet diffusion. Investments in these areas may be driven by demand, and depend on many interacting decisions by organizations and governmental bodies. Governmental policy may range from acknowledgement of the importance of the Internet in public pronouncements to policies that encourage, support, or mandate its use [King et al. 1994]. By incorporating an institutional focus, these three dimensions represent three broad ways to characterize the Internet-related NSI of a country, and give a sense of how the NSI is shaping Internet diffusion.[8]

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[8]Institutional views have been taken by Daly [1999] and the "Internet Counts" project with which he has been affiliated [Wilson et al. 1998]. The Leland Initiative Telematics for Africa project at the Center for International Development and Conflict Management (CIDCM) at the University of Maryland is developing an instrument for Internet assessment that is highly focused on institutions and uses qualitative data gathering techniques [bridges.org 2001].

Another stream of NSI research concerns the NSI as a "learning economy" [Lundvall 1999]. Our sophistication of use dimension reflects this learning ability or absorptive capacity of users within the country by giving a sense of the extent to which they have learned to use (and create) increasingly sophisticated aspects of the Internet and the applications it provides. This dimension compensates, to a certain extent, for the inability to survey every use of every Internet-based technology in all countries of the world. It also reflects the NSI, as the NSI is very much concerned with education and training, and also influences the climate of innovation that can make innovations available to sophisticated users.

Standing behind our dimensions, and helping to establish their values, are determinants that reflect the nature of the NSI of a country. These determinants are consistent with work by Nelson [1993], Porter [1998], and others, but do not represent a general theory of Internet diffusion.[9] Section IV of this paper takes up the question of how to apply the GDI scales and lists determinants that we find particularly useful to consider.

Partly because NSI researchers themselves do not consider the systems of innovation approach to be a fully developed theory, but more of "conceptual framework" [Edquist 1997, 2], considerable work has been done to relate the NSI approach to evolutionary theory by using biological analogies.[10] In this formulation, innovations arise not because of a direct need for survival, but because of an innate

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[9]The GDI work grew out of a similar approach to measuring the information systems capability of a nation, developed by Wolcott et al. [1996]. Sharif [1988] provided an important example of technology assessment measurement, and Liff et al. [1993] provided an important example of devising dimensions. It is beyond the scope of this paper to formulate an overarching theory of Internet diffusion and to relate it to other general models of Internet diffusion which have already been developed. Daly [2000] has proposed a conceptual framework that interrelates Internet penetration, utilization, and impacts. His model includes many of the same dimensions and determinants as contained in our model. Bazar and Boalch [1997] also put forth a general model of Internet diffusion that has some similarities with our model. Abramson [2000, pg. 70] characterizes our methodology as a "sophisticated adjunct" to "country-by-country Internet user counts," which of course does not capture the full richness of our dimensions and determinants.

[10]A somewhat different focus was taken by Basalla [1988], who related evolutionary analogies to the history of technology. The growing field of evolutionary economics represents another application of evolutionary analogies [cf. Nelson and Winter 1982].

pleasure taken by humans in novelty [Basalla 1988]. Concepts of diversity, variation, and natural selection must be adapted to study human innovations.

> In economic systems variation is essentially created by search activities, all those activities that scan the environment searching for alternatives to existing routines. Variation creates a large number of potential species/technologies, accompanied by new routines, only some of which are sufficiently adapted to the environment. The less adapted ones are eliminated by selection. Selection is the result of a series of processes, like competition and several forms of regulation. [Saviotti 1997, pg. 188]

Evolutionary theories predict that national systems of innovation will exhibit characteristics of *path dependence,* whereby variations in technologies and routines will largely be dependent on what has existed previously; *irreversibility,* whereby countries are unlikely to revert to previous states; and *multistability,* whereby it is posited that more than one stable state may arise from the existence of similar outcomes [Saviotti 1997]. Path dependence and irreversibility are fundamental principles that underlie the development of evolutionary systems of classification, and lead to the use of common characteristics to make inferences about which entities evolved from which other entities [Ridley 1986]. When applied to technologies, these principles support the idea that measurement scales should reflect increasing sophistication and complexity. An evolutionary explanation was proposed, for example, by Ein-Dor and Segev [1993] in their examination of the development of information system types.[11] The GDI dimension scales specifically embody these concepts of increasing sophistication and complexity. They are consistent with broad, underlying theories of how national systems of innovation work.

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[11] Their work differs from ours, however, in that they were trying to characterize information systems themselves. We are trying to find characteristics that reflect the extent of adoption of an innovation (not the innovation *per se*). In examining properties, functions, and the timing of the introduction of new systems, Ein-Dor and Segev [1993] adopted a combination of phenetic, teleological, and phylogenetic approaches that mirror the traditional methods of evolutionary taxonomy. See Ridley [1986].

A third body of theory, diffusion of innovations (DOI), has been most extensively elaborated by Everett Rogers [1986, 1995]. Although not a universal theory, the Rogers model is based on examination of thousands of studies which span a large number of fields of human endeavor, and "has quite rightly had a profound role in shaping the basic concepts, terminology, and scope of the field" [Fichman 2000, pg. 107]. Innovation diffusion is "the process by which an innovation is communicated through certain channels over time among the members of a social system. It is a special type of communication, in that the messages are concerned with new ideas" [Rogers 1995, pg. 5]. DOI theory is concerned with the mechanisms by which innovations are communicated and selected. It may be seen as one of the constituent processes within a more general evolutionary explanation, although this proposition has not yet been examined in detail.

According to Rogers [1995],[12] an innovation is something perceived as new by potential adopters, who may be divided into categories such as innovators, early adopters, early and late majority, and laggards depending on how willing they are to take a risk with something new. The rate of adoption depends on the characteristics of the innovation, and we therefore examine various aspects of the technology cluster in assigning several dimension values. Adoption also depends on communication channels by which information is transmitted, and the social system of potential adopters, which again emphasizes that the country level is appropriate. Adoption decisions may be made by individuals (optional), within organizations (collective), or by some authority such as the state (authority). Pervasiveness and sectoral absorption measures represent use at these levels. Adoption may be understood as trying the innovation out (implementation) and deciding to continue using it (confirmation), an insight that is incorporated in our sophistication of use measure [Rogers 1995].

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[12]An easily accessible summary of his theory may be found in Rogers and Scott [1997].

Within the IS field there is a sizeable body of literature that uses the DOI approach. Because Rogers' model does not apply equally well in all cases, IS researchers have developed “middle range” theories that are oriented toward specific technologies and/or adoption contexts [Fichman 2000]. Prescott and Conger [1995] have usefully classified this literature by the “locus of technology impact” and “the research approach.” Technology impacts have been studied at the level of IS departments themselves, within organizations more generally, or across organizations. Research approaches have focused on the relationships of various factors (i.e., what determines diffusion), or on understanding what happens during the diffusion process at various stages (the stage approach). Research taking the factor approach resembles typical diffusion studies by using some form of adoption, generally by individuals, as the dependent variable [Prescott and Conger 1995].

This literature supports our framework in two ways. First, studies of the impact of inter-organizational systems within this tradition found critical mass (i.e., network externalities) to be an important explanatory variable for their diffusion, and thus indirectly support our treatment of the Internet as a technology cluster [Prescott and Conger 1995].

Second, this literature supports our use of a qualitative, process-oriented research approach. IS researchers taking the stage approach have studied the processes by which new systems are created and incorporated into business processes or organizations. Using qualitative methods, adoption is understood as a multifaceted phenomenon that takes place in a variety of ways over time. The qualitative approach does not constrain the analysis to any predetermined variables. It allows the researcher to examine the “rich organizational and political processes whereby a given set of information technology is instantiated” [Lee 1999]. Furthermore, it has long been recognized that interpretive methods, along with surveys and possibly field experiments and case studies, are most appropriate for studying information systems phenomena at the level of a society [cf. Galliers and Land 1987].

Thus we find in the IS literature itself strong justification for viewing adoption as a multifaceted construct and taking a qualitative approach in determining the value of the dimensions. Our measures, particularly sophistication of use, view Internet diffusion as a process that passes through typical and definable stages. GDI studies have often been exploratory, in countries where little or no exhaustive research on the Internet has yet been done. Countries comprise many people and numerous organizations, so to try to understand the general level of Internet diffusion in a country, we must be cognizant of multiple instantiation processes in differing circumstances even within one country. Rather than constraining or prescribing the use of any particular data, the GDI framework encourages researchers to consider any available sources.

OTHER INTERNET DIFFUSION WORK

We are now in a position to characterize other research work that has tried to measure the status of Internet diffusion in various countries (Table 10). These may be grouped into four categories: (1) studies grounded in traffic patterns and data collection from the Internet itself, (2) studies based on survey research and statistical samples, (3) estimates and derived indexes that are based on self-assessment or syntheses of other studies, and (4) quantitative modeling approaches. Table 10 is a representative but not necessarily exhaustive list of these approaches and references where more information may be found about them. Press [1997b] presented one of the first survey articles about on-going measurement techniques. Daly [1999] and Abramson [2000] have also characterized and provided references to a number of these approaches, and Bridges.org [2001] has compared a number of them.[13]

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[13]Larry Press provides a web page with links to many of the Internet measurement efforts. See **http://som.csudh.edu/fac/lpress/GDIFF/GDIFFprojects.htm**. Hal Varian also maintains a page about Internet metrics at **http://www.sims.berkeley.edu/resources/infoecon/Accounting.html**. An extensive list of references to all aspects of Internet measurement is maintained by Martin Dodge [2000] at **http://www.cybergeography.org** (also see Dodge [1998].

Table 10. Other Research on Internet Diffusion

Technique	Representative Users and References
1. Net-Based Collection	
Sending/receiving e-mails	Larry Landweber (**ftp://ftp.cs.wisc.edu/connectivity_table/**); Olivie Crepin-Leblond (**http://www.nsrc.org/oclb/**)
Automated discovery of number and location of hosts	Network Wizards' Internet Domain Survey (Internet Software Consortium 2001]; Matrix.Net [Matrix.Net 2000]; Netcraft Web Server Survey [Netcraft 2000] ; RIPE NCC [2000]
WWW Pages	Lawrence and Giles [2000]
Topology and Internet "weather reports"	Cooperative Association for Internet Data Analysis (CAIDA, **http://www.caida.org/**); Claffy [1996, 1999]; Monk and Claffy [1996]; Monk [2000]; Burch and Cheswick [1999]; TeleGeography [Staple 1999]; Andover Advanced Technologies, Inc. [2000]
2. Survey Research and Samples	
Internet size based on IP address samples	Telcordia Technologies [2000a, 2000b]
Panels of representative WWW users	MediaMetrix, A. C. Neilsen, other marketing research firms. (See Rood [1999] for a cautionary view.)
Surveys with convenience/non-representative samples	Graphics, Visualization and Usability (GVU) Center at Georgia Institute of Technology [Georgia Institute of Technology 1999]
Other surveys	WITSA [2000]
3. Syntheses/Indexes	
Survey of available other statistics	Nua Internet Surveys [2000]; Nua Internet Surveys [2001]; Cyberatlas (**http://www.cyberatlas.com**)
Indexes/self-assessments	CSPP Readiness Guide for Living in the Networked World [CSPP 1998]; Internet Counts Project [Wilson et al. 1998]; The IDC/World Times Index [IDC 2001]; Meta Group Global New E-Economy Index (GNEI) [Foley 2000; Meta Group 2000]; The Economist Intelligence Unit E-Readiness Index [Foley 2000]; Readiness for the Networked World [CID 2000]; McConnell International E-Readiness Index [McConnell International 2000]; APEC E-Commerce Readiness Guide [APEC 2000]
4. Quantitative Modeling	
Fitting number of hosts to S-curves	Gurbaxani [1990]; Rai et al. [1998];
Using regression analysis	Hargittai [1999]; Kedzie [1997], Maitland and Bauer [2001]; Robinson and Crenshaw [1999]
Using "coupled hazard" approach	Dekimpe, Marnik, and Savary [2000]

The principle contribution of the net-based collections techniques is to establish and determine the actual extent of Internet diffusion. Sending and receiving e-mails to and from a country, for example, was an easy way to see which countries were connected. While these techniques can, to a certain extent, tell us what is where, they are most useful as input to more complete diffusion studies.

Most quantitative Internet studies have used one single dependent variable, adoption.[14] Most are variance studies in that they try to relate a variety of exogenous factors to this decision. They have generally used the number of hosts as the surrogate for Internet diffusion in a country, and thus the conclusions which may be drawn from them have been limited. Hargittai [1999], for example, acknowledges that qualitative factors are needed to enhance the conclusions that can be drawn from quantitative studies, while pointing out that quantitative studies help define the most important variables of interest. However, finding suitable statistics for measuring these exogenous variables has been problematic (e.g., Hargittai was only able to include 18 countries in her analysis). Maitland and Bauer [2001] contend that because DOI theory is centered on users' perceptions of technology, it must be modified when considering such national level characteristics as infrastructure, which do not depend on individual adoption decisions. They would see teledensity as exogenous to Internet adoption, whereas we see it as a part of the Internet technology cluster. The development of the telecommunications infrastructure is, after all, intimately tied to demand spurred by Internet use.

A very large number of surveys have been done, some using representative samples and others using convenience samples. Similarly, other forms of indexes have been used, some of which sound rather similar to our approach.[15] While a

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[14]Buselle et al. [1999] discuss various approaches to Internet diffusion studies, but all involve adoption as the dependent variable. One typical example of such a study is Teo and Tan [1998].

[15]For example, the IDC/World Times Information Society Index (ISI) aggregates available national-level indicators by category into four measures: computer infrastructure, information infrastructure, Internet infrastructure, and social infrastructure. The social infrastructure consists of "Civil liberties, Newspaper readership per capita, Press freedom, Secondary school enrollment, and Tertiary school enrollment." Sources include IDC, UNESCO, ITU, World Bank, and Freedom House. These are aggregated to form a single index. See World Times/IDC [2000]. This is a good example of a method that does not directly measure Internet diffusion.

detailed examination of these measures is beyond the scope of this paper, we assert that, when taken alone, they are problematical because they may be too narrow in scope or unrepresentative, they may use questionable methodologies, or they may involve too many assumptions to be useful in practice. GDI studies often make careful use of data derived from many of these approaches and appear to be most comprehensive in this regard [bridges.org 2001].

IV. APPLYING THE FRAMEWORK AND A BRIEF CASE STUDY

The GDI framework has been applied by MOSAIC Group members and others in order to study the status of the Internet in about 25 countries (see Table 11). As noted in section III, the GDI methodology is fundamentally qualitative, permitting the researcher to gather data from as many diverse sources as possible.[16] The following non-exhaustive list represents the types of sources we frequently consult. Many of these activities are carried out in parallel, and sources may be revisited as new information becomes available:

- collecting any available data from existing sources, including other studies, press reports, net-based collections methods, etc.
- collecting primary data from the Internet/WWW itself. For example, surfing web pages of ISPs can be quite helpful
- gathering expert opinions using Delphi-type processes or asking for self-assessment using the GDI scales
- interviewing stakeholders face-to-face in the country, at conferences, etc., and via e-mail communications with them
- consulting universities, regulatory agencies, governmental bodies, NGOs, development agencies, etc.
- carrying out focus groups and/or mounting actual larger-sample surveys on or off the Internet. Collection of quantitative data is not excluded, and GDI

[16]Sudweeks and Simoff [1999] provide a means for integrating quantitative and qualitative approaches in Internet research that is similar to the GDI methodology. Both ultimately make interpretation central.

studies may give rise to increasingly quantitative approaches (not excluding testable hypotheses) at some point in the future.

Table 11. Country Studies Done Using the GDI Methodology as of Mid-2000[a]

Country/Region	**Reference(s)**
Bahrain	Goodman et al. [1998b]
Bangladesh	Press and Goodman [1999]
Bosnia and Herzegovina	Goodman et al. [1998b]
China	Goodman et al. [1998a, 1998b]; Foster and Goodman [2000]; Foster et al. [1999]; Press et al. [1999];
Cuba	Goodman et al. [1998b]; Press [1998]
Finland	Goodman et al. [1998b]
Historical Palestine	Ein-Dor et al. [2000]
Hong Kong	Foster et al. [1999]
India	Goodman et al. [1998b]; Press [1999]; Wolcott [1999c]
Iran	Goodman et al. [1998b]
Iraq	Goodman et al. [1998b]
Israel	Ein-Dor et al. [1999b]
Jordan	Ein-Dor et al. [1999a]
Kingdom of Saudi Arabia	Goodman et al. [1998b]
Kuwait	Goodman et al. [1998b]
Nepal	Goodman et al. [2000]
Oman	Goodman et al. [1998b]
Pakistan	Wolcott [1999a]; Wolcott and Goodman [2000]
Qatar	Goodman et al. [1998b]
Singapore	Press [1997a]
Taiwan	Foster et al. [1999]
Turkey	Wolcott[1999c], Wolcott and Goodman [2000]
Uganda	Minges et al. [2000]
United Arab Emirates	Goodman et al. [1998b]
Yemen	Goodman et al. [1998b]

[a]Preliminary studies have also been done of Russia [Perov and McHenry 2000], the Phillippines [Connally 2000], and other countries. Work derived from and related to this project includes Burkhart and Goodman [1998], Burkhart et al. [1998], Tan et al. [1999], and Wolcott and Cagiltay [2001].

Although a considerable amount of data is sometimes available from published and/or Internet sources, it is often incomplete and sometimes contradictory. As a hypothetical example, if one source claims 50% of the population uses the Internet, yet another says that only 10% has access to computers at home or work, further information is needed to resolve this discrepancy. We do not simply average the two numbers to get 30%.

We find it highly useful to visit a country in the course of preparing a country study. Interviews with a cross section of decision makers drawn from government, academia, and the Internet business community are invaluable for understanding not only the dimensions, but particularly the determinants of Internet diffusion (Table 12). The interview format often allows us to present a picture of the determinants and to get valuable feedback and insights. In doing interviews, collecting existing information from secondary sources, guiding self-assessments, etc., researchers applying the GDI methodology typically develop a mental model of which factors play the most important role in determining how and why the Internet is diffusing. We then can present our conceptualization to new interviewees to see if they have a different perspective or anything to add. As each additional interviewee (and information source) begins to add less and less new information, we begin to have confidence in our evaluation of the dimensions and determinants for that particular country. In this sense we are applying the concept of the hermeneutic circle as expounded by Lee [1999]. Our interviewing methodology draws on qualitative interviewing [Rubin and Rubin 1995].

Can the GDI methodology be applied by other researchers?[17] Certainly, we consider the dimensions and their definitions to be clear enough that they can easily be assigned when the necessary information is available. The more ambiguous and obscure the source information, the more necessary it may be to fill in the gaps by

[17]The GDI methodology has been used by other researchers studying Iran [Adibi *et al*. 1999] and Uganda [Minges et al. 2000]. Numerous master's level papers have been written as well by various students of some of the authors.

examining determinants. There is no doubt that experience helps the researcher using the GDI methodology to ask the necessary questions and essentially look in the right places for the needed information.

Table 12. Determinants of Internet Diffusion

QUALITIES OF THE TECHNOLOGY ITSELF	
1. Perceived value	Similar to relative advantage in traditional diffusion studies
2. Ease of use of the Internet	Similar to complexity and compatibility, this may also entail looking at literacy and availability of local-language content
3. Cost of Internet access	Having to do with relative advantage and trialability, it may also entail looking at Internet costs relative to income levels
INTER-RELATIONSHIPS WITHIN THE TECHNOLOGY CLUSTER	
4. Access to constituent technologies	Looks at the balance between all the technologies that must be present for various levels of use
5. Demand for capacity, multiplicity of ISPs, services provided	How demand at various levels of the cluster is driving the connectivity infrastructure development
EXTERNAL/SURROUNDING FORCES	
6. Geography	How physical geography influences Internet development
7. Adequacy and fluidity of resources	A broad category considering financial, informational, human, technological or capital, and material resources and the ease with which they can flow from where they are to where they are needed
8. Ability to execute	The ability to develop a sound strategy and a suitable design given opportunities and constraints, and the ability to manage plans through to completion
9. Culture of entrepreneurship	How entrepreneurship is rewarded, both at the organizational and individual level
10. Regulatory/legal framework	Specific laws and regulations influencing Internet diffusion
11. Forces for change	Such things as competitive environment, presence of demanding domestic customers, rate of creation of new organizations, presence of champions
12. Enablers of change	Conditions that allow a community to accept and incorporate change, including institutional, historical, cultural, and educational factors

As noted in section III, we do not claim that the set of determinants we typically investigate represents a general theory of Internet diffusion. Our process of observing and deriving these determinants has been an inductive one, carried out on the basis of choosing and studying a widely diverse set of countries. These studies confirmed the importance of this set of determinants, and the set that we list here is obviously a subset of all possible factors that might influence innovation decisions. We do not view them as primary causal forces, nor are they all completely independent of one another. We present them as useful guidelines (a checklist) for thorough data collection and analysis, and leave the development of grounded theory on the basis of these studies for future work [Glasser and Strauss 1967]. It may not be necessary to examine these determinants in detail before assigning some of the dimension values.

These determinants highlight three central elements of Rogers' diffusion of innovation model: the innovation/technology cluster's characteristics, adopters and adoption decisions, and the surrounding social/economic/regulatory system. Important characteristics of the innovation are whether or not it offers advantages relative to other innovations or existing ways of doing things (relative advantage); how compatible it is with existing values, beliefs, needs, and previously adopted ideas (compatibility); how complex it is to understand and use (complexity); how easy it is to try it out (trialability); and how easy it is to observe (observability) [Rogers 1995]. Our model does not start, as Rogers' does, with the elements that directly influence the adoption decision, but looks one or more levels back in the chain of determination in order to find which factors make the most difference in any given country. Thus, as elaborated in Section III, our analyses are strongly influenced by the national systems of innovation approach [Edquist 1997], and pay particular attention to the role of government policies that may encourage or mandate Internet development and adoption [King et al. 1994].

Rather than providing extensive definitions and examples of these determinants, we provide a small example that illustrates some of their application in practice. Our first analysis of the state of the Internet in Cuba was performed in 1997 [Press 1998]. Figure 4 shows the ease with which the reader can quickly grasp the status of the Internet in Cuba using the Kiviat diagram. Succinct justifications for the dimension assessments (as of 1997) supplement the diagram (the numbers in parentheses refer to Table 12).

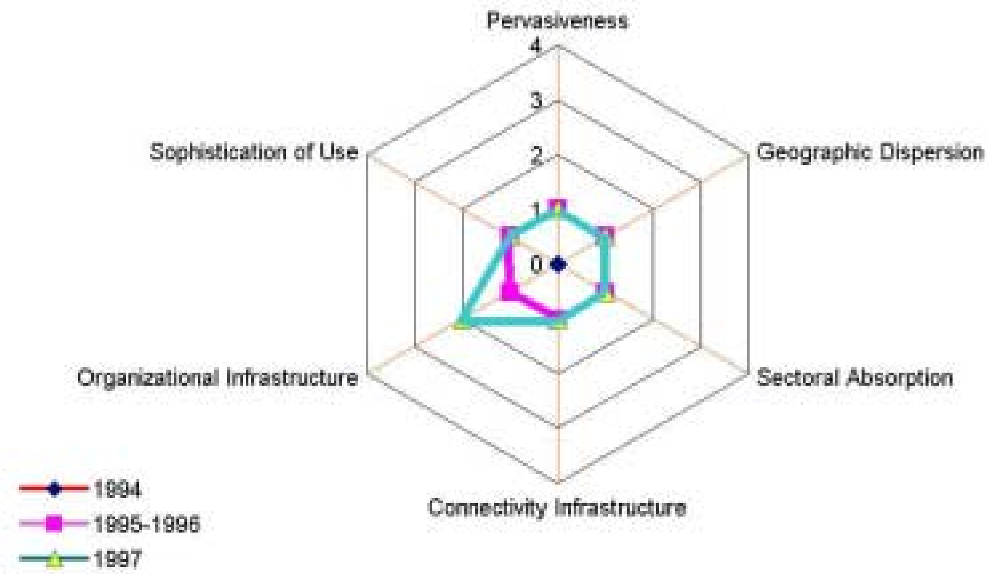

Figure 4. GDI Analysis of Cuba, 1994-1997

Pervasiveness: Cuban IP connectivity was at the embryonic level, with perhaps as few as 100 users. Even if we had included UUCP email accounts, less than 1/1,000 of the population used them. However, it was noteworthy that e-mail use extended well beyond the network technician community. Home use essentially did not exist, and access everywhere was limited by high cost (3) and absence of telephone infrastructure (4). This was partially determined by the absence of resources (7); the difficulty of attracting capital to an impoverished Communist nation that the U.S. was embargoing might be interpreted as an inability to execute (8). Most important was value as perceived by the government (1). On the one hand, use at work could be justified in an atmosphere in which the government saw positive value in the promotion of cultural values such as health care, education, and urban-rural equality. It also recognized the economic value of the Internet in the promotion of hard-currency generating industries such as medical instruments, and health and leisure tourism. On the other hand, it wished to restrict content and the potential use of networks for U.S. propaganda and/or by subversive elements (1).

This dichotomy slowed the development of the Internet between 1995 and 1997, influencing all the other dimensions.

Geographic Dispersion: The only IP point of presence offering network connectivity in Cuba was at the Center for Automated Exchange of Information (CENIAI) in Havana. However, taking into account e-mail connectivity, we found access in every province and nearly every municipality. So, while Cuba was rated at the single location level because of limited IP connectivity, there was considerable interest in geographic dispersion. This could be considered an enabler of change (12), and represented cultural values noted under pervasiveness. Such dispersion was atypical of poor nations.

Sectoral Absorption: IP connectivity was minimal in the health and government sectors, and nonexistent in education and commerce, giving Cuba a rare overall ranking. On the other hand, UUCP-based e-mail was used in the health sector throughout the nation, more than 10% of the ministries had e-mail accounts, and the Youth Computer Clubs (education sector) were nationwide (1). The absence of an entrepreneurial culture (9) in a planned economy and the absence of a business sector inhibited commercial use, while emphasis on the education and health sectors was a force in favor of change (11).

Connectivity Infrastructure: While Cuba had an international IP link, it had no domestic backbone and barely any leased line access, placing it at the low end of Level 1 (thin) on this dimension. Cuba was severely hampered here by its poor telephone infrastructure and its historical concentration on the X.25 protocol (4, 12). Low levels of investment in telecommunications reflect different government priorities, but also the overall inadequacy and lack of fluidity of resources (7). However, the populist history of Cuba influenced decisions to expand the infrastructure outside the capital, thus serving as a force for change (11).

Organizational Infrastructure: While not independent businesses, CENIAI and Teledatos[18] both provided connectivity to organizations with networks, and there was some evidence of competition between them (either by design or historical development (12)). There was also a degree of coordination provided by the Interministerial Commission for Networking. On this basis, we ranked Cuba at the controlled level. Prospects for allowing a more competitive environment seemed slim (9) given concerns about political stability, the recent Soviet experience being foremost in mind (12).

Sophistication of Use: As there was little IP connectivity, Cuba had to be ranked at the minimal level; however, e-mail and information retrieval from e-mail driven servers reached the conventional level in the health care and bio-technology communities. We felt that the poor telephone network (4) and absence of private enterprise (7) would inhibit sophisticated uses of the Internet for some time to come. On the other hand, uses in the social sphere (e.g., for enabling lower cost health care) represented positive perceived value (1) and the possibility of some transformation in business processes (11).

The most significant determinants, therefore, were the perceived value and cost (1, 3), access to constituent technologies (4), resources (7), entrepreneurship (9), forces for/against change (11), and enablers/inhibitors of change (12). These policies, which ultimately stemmed from the decision to be a Communist nation and concerns about the recent Soviet experience, also led to an unusual emphasis on the use of the Internet in the social sphere. This was a counterbalancing force that could somewhat offset these inhibitors. It is also interesting to note that at this level of use by a mainly technical community, ease of use (2) had not begun to play much of a role. Drivers of demand for capacity (5) had started to appear as the CENIAI international link had become badly overloaded, but were dampened by a lack of critical mass and the role of centralized planning. Physical geography (6)

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[18]Teledatos mainly offered UUCP connections over an X.25, but was upgrading their X.25 backbone in late 1997 so that they could run IP over X.25.

played a large role in the political fortunes of Cuba, but not in the deployment of the Internet *per se*. Finally, the Cuban government exercised control less through formal regulations and laws (10) than through controlling access and through more pervasive, less transparent means of inhibiting socially risky communication.

The GDI methodology helped us to sift through the enormous amount of available data in order to weigh which dimensions were most important and what factors played the most significant roles in determining them. Even this brief Cuba analysis represents a sizeable amount of underlying research and analytical work.

V. CONCLUSION

The most common means for comparing the status of the Internet in various countries has been to use number of users or number of hosts. The GDI methodology provides a measurement scale that captures the status of the principal components of the technology cluster that comprises the Internet. Since it encompasses all major parts of the cluster, it provides a much better picture of Internet status than any single-valued measure. The significance of the measures are easy to grasp when graphed on a Kiviat diagram. The GDI scale can be applied over time to paint a picture of the speed with which the Internet is being diffused. When enough countries have been characterized using this method, we will have a much clearer picture of global Internet diffusion.

Having been used for about 25 countries so far, the GDI measures have proven to be sufficiently robust for widespread application. The nation-state is an appropriate unit of analysis for diffusion. While a learning curve will be necessary for some other researchers to apply the methodology in full, including full-blown exploration of the determinants, the measures themselves are sufficiently clear that they may be understood and applied by a wide variety of potential users. A concerted effort by many interested parties around the world could result in the rapid characterization of the Internet status in many countries.

Results of the GDI studies will prove useful for several stakeholder groups. Those in business should get a clearer picture of what they can expect to find when investing and doing business in a given country. Internal and external policymakers can get a better idea of what needs to be done to eliminate bottlenecks and push Internet development and use forward. Studies done using this framework contribute to the debate over what levers are available to policy-makers at the national and international level to influence, shape, and positively (or negatively) influence the Internet's development, use, and growth.

Researchers can deepen their understanding of diffusion in general and the diffusion of the Internet in particular. The more the researcher understands and applies the determinants, the deeper and better justified that analysis can be. We hope to write an extensive companion paper to this one about the determinants. Having a uniform set of metrics for Internet diffusion that can be used on a global scale will immensely facilitate empirical diffusion studies.

Other plans for the GDI group include doing more studies of other countries and updating some studies we have already done, continuing to review the scales while taking into account the need for longitudinal consistency, working on the development of a grounded theory of Internet diffusion, and working toward a synthesis of the results to date.

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[19]Editor's Note: The following reference list contains hyperlinks to World Wide Web pages. Readers with the ability to access the Web directly or are reading the paper on the Web can gain direct access to these linked references. Readers are warned, however, that

1. these links existed as of the date of publication but are not guaranteed to be working thereafter.
2. the contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.
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Peter Wolcott is an Associate Professor in the Department of Information Systems and Quantitative Analysis, College of Information Science & Technology, at the University of Nebraska at Omaha. Professor Wolcott has long-standing interests in the international dimensions of information technologies. His other research focus has been on the international aspects of high-performance computing. His doctoral work involved an examination of the high-performance computing (HPC) sector of the former Soviet Union. More recent work includes a study of the U.S. HPC export control regime.

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