INFORMATION TECHNOLOGY AND SUSTAINABLE DEVELOPMENT: UNDERSTANDING LINKAGES IN THEORY AND PRACTICE

by

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ABSTRACT

Sustainable development is one of the most significant societal challenges of the 21st century. One global trend with significant implications for sustainable development is the extraordinarily rapid development and application of information technology (IT), often referred to as the "IT revolution."

As a result of the "IT revolution," there have been many efforts to leverage IT for sustainable development, particularly in the context of empowering developing countries. The first main finding of this thesis is that IT can be leveraged effectively to facilitate transitions to sustainability so long as potential negative linkages are identified and addressed adequately. To help understand this dynamic, this thesis develops a conceptual framework of the positive and negative linkages between IT and sustainability.

A case study, the Global System for Sustainable Development (GSSD), is presented to put the conceptual linkages into context. GSSD is a global knowledge network devoted to sustainability issues. The experiences accumulated over the last two years from the development and management of GSSD help to illustrate significant institutional, organizational, and technical barriers to leveraging IT for sustainability. One major contribution of this thesis is the formulation and implementation of an innovative global workflow process to address these issues.

The GSSD case study leads to another major finding of this thesis, which is that IT can effectively facilitate transitions to sustainability as long as the technology is customized to address critical institutional and organizational barriers. This finding is especially important in the context of cultural diversity and an increasingly globalized world.

The main contribution of this thesis is a new strategic methodology for assessing the impact of IT advances on prospects for sustainable development. The approach consists of two main elements: (1) analysis of the linkages between the IT tool and sustainability goals and (2) identification of critical institutional and organizational contexts and barriers, and customization of the IT tool to address these issues. Strategic consideration of these elements will help to unleash the enormous potential of IT for sustainable development.

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1. Introduction

1.1 Current Trends and Context

Sustainable development, also referred to as sustainability, is one of the most significant societal challenges of the 21st century. The Brundtland Commission, in its widely accepted and referenced statement, defines sustainable development as meeting "the needs of the present without compromising the ability of future generations to meet their own needs[1]." Beyond this definition, there is not much consensus about the specific operational meaning of sustainable development. As illustrated in Table 1.1, the diversity and, at times, divergence among various approaches to sustainability issues, stems from the wide array of definitions for "sustainable development."

What is to be **sustained?**	***For how long?*** • *25 years* • *"Now and in the future"* • *Forever*	What is to be **developed?**
Nature • Earth • Biodiversity • Ecosystems **Life Support** • Ecosystem Services • Resources • Environment **Community** • Cultures • Groups • Places	***Linked by:*** • *Only* • *Mostly* • *But* • *And* • *Or*	**People** • Child Survival • Life Expectancy • Education • Equity • Equal Opportunity **Economy** • Wealth • Productive Sectors • Consumption **Society** • Institutions • Social Capital • States • Regions

Table 1.1 Varying Definitions and Perspectives of Sustainable Development
Source: National Research Council (1999)

The issue of conceptual ambiguity is still prevalent, as illustrated by the vast diversity in approaches utilized by various institutions, as revealed by the literature review in Section 2 and

[1] World Commission on Environment and Development (1987).

highlighted in Section 3.2. The premise of this thesis is that the aim of sustainability is to attain a state of maintained economic and social development that does not dwindle or destroy the natural resources used for current and future prosperity. This broad definition attains further refinement in scope and focus in Sections 3 and 4 of this thesis, and even further operationalization in Section 5.1, when a conceptual framework for sustainability is discussed[2].

A global trend with significant implications for sustainable development is the extraordinarily rapid development and application of information technology (IT)[3], often referred to as the "IT revolution." By drastically reducing the cost of information and communication, IT advances have had tremendous economic effects. By helping to drive the globalization of markets and contributing to a greater knowledge intensity of economies, IT has led to the "knowledge-based economy[4]," also known as the "new economy[5]" or "weightless economy[6]." Figure 1.1 illustrates how IT has helped to drive knowledge-intensity growth in economic development.

[2] The conceptual framework is explained in detail in Choucri (2000).
[3] This paper uses the term "IT" to refer to hardware, software, telecommunications, and Internet technologies.
[4] OECD (1996).
[5] OECD (2000).
[6] Economist (2000).

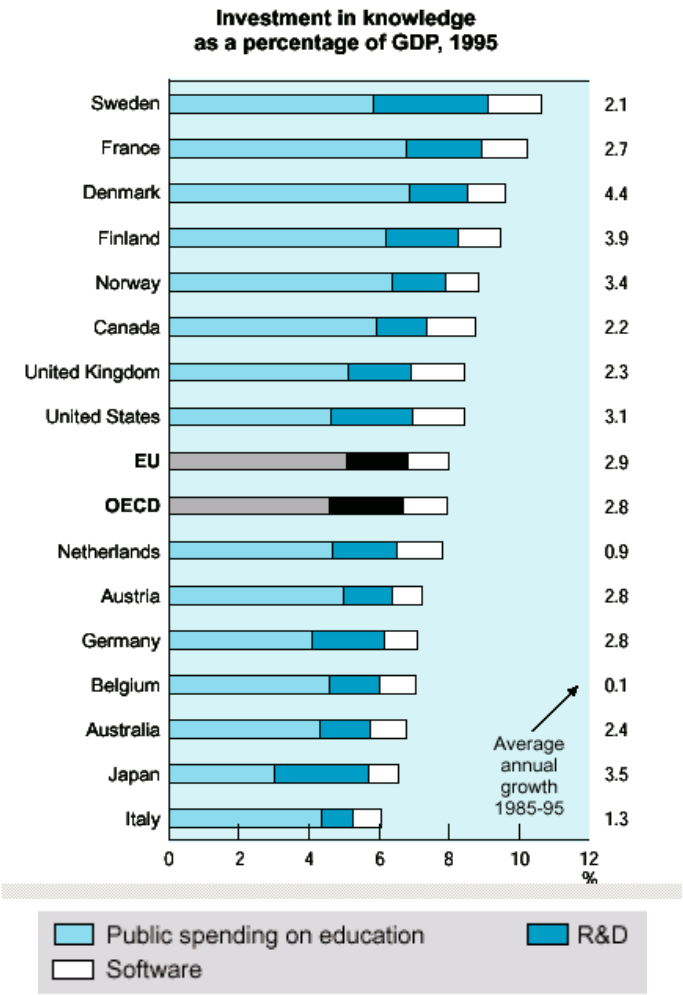


Figure 1.1 Knowledge Intensity of Today's Economies
Source: OECD (1999)

Despite the economic downturn that began in 2000 and continues today, IT continues to play a significant role in economic prosperity. Figure 1.2 illustrates how IT is contributing a significant share to the productivity growth of many countries.

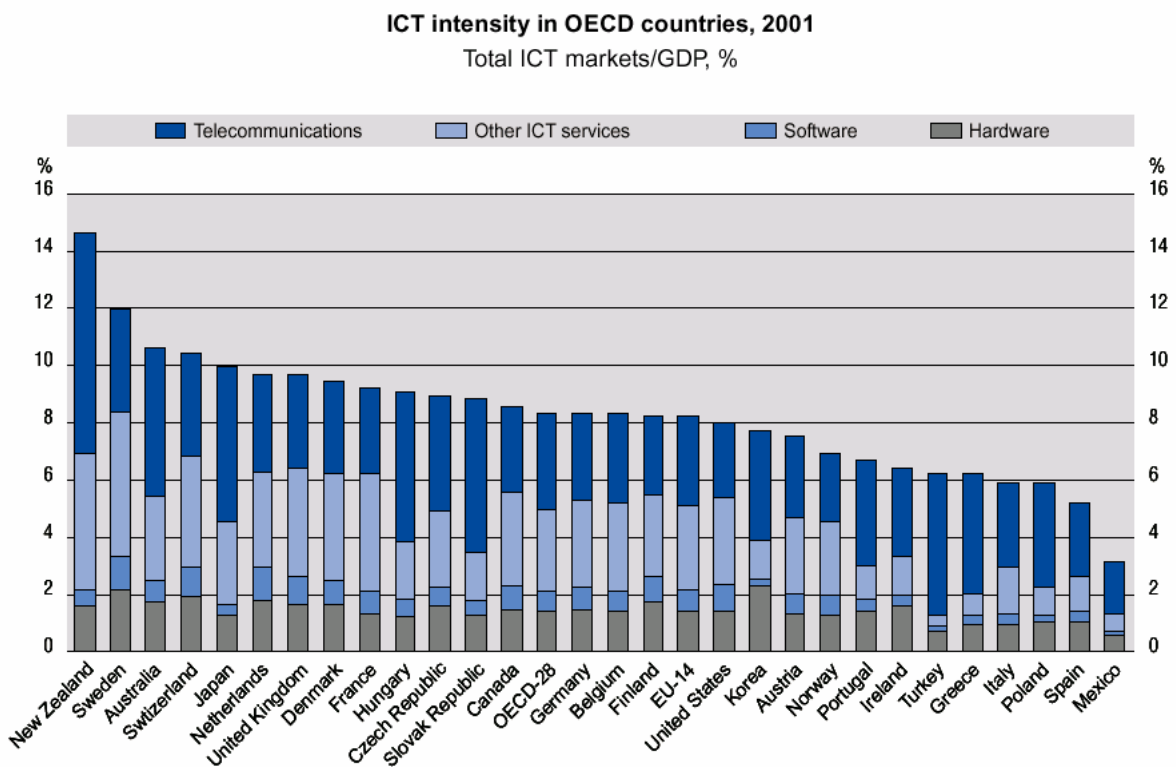


Figure 1.2 IT Contribution to Gross Domestic Product, 2001
Source: OECD (2002)

1.2 Significant Challenges

Sustainable development represents a significant global challenge by forcing society to balance the desire to prosper economically with the responsibility to ensure continued social development and environmental protection. Developing countries are particularly vulnerable and face tremendous obstacles to sustainability. As a result, many efforts have been focused on IT as a potentially powerful, yet accessible and affordable, means to facilitate the transition towards sustainability. For example, there are a significant number of international initiatives focused on the potential role of IT in the empowerment of developing countries.[7]

However, the linkages between IT and development, positive as well as negative, need to be better understood to determine *which* issues can be effectively addressed using IT, *how* IT tools can be used, and in *what context* should the technology be implemented. Deepening "digital" and "knowledge" divides, over-reliance on IT as a panacea to all problems, and environmental rebound effects are among the factors that affect a country's ability to implement effective IT strategies for sustainable development. Therefore, this consideration of linkages is a critical gap in the current research on IT and sustainable development and frames a key focus of this thesis.

[7] For example, see projects implemented by UNDP's Info21 (http://www.undp.org/info21/), World Bank's InfoDev (http://www.infodev.org/), and UN's ICT Task Force (http://www.unicttaskforce.org/).

1.3 Thesis Objectives

This thesis intends to focus on the challenges related to leveraging applications of IT for sustainable development. In some cases, IT advances will likely help to alleviate obstacles to sustainable development, while in other cases, IT may have a counter-productive effect. This study seeks to highlight both positive and negative attributes of IT, in order to gain a more comprehensive understanding of how IT affects sustainability.

The focus of this thesis is on a case study of an IT application for sustainable development, known as the Global System for Sustainable Development (GSSD). The GSSD case study helps to illustrate how IT has the potential to play an enabling role for sustainability, as long as potential limitations and rebound effects are identified and addressed adequately.

The GSSD case study also illustrates the importance of non-technical factors to IT feasibility assessments, such as organizational and institutional constraints, and ways in which they have impacts on the applications of the technology. *This study seeks to demonstrate how such factors can hinder the effectiveness of IT implementation and, conversely, spur the invention of a new IT tool to address these issues.* In this context, the thesis shows how an innovative global workflow tool was developed and implemented for the GSSD project.

Overall, this thesis contributes to current research on IT and sustainability specifically by presenting *a new methodology* for strategically assessing potential impacts of IT on reaching sustainability-supporting objectives. The methodology consists of a theoretical component which identifies key linkages of IT and sustainability. The empirical contributions to the methodology are a result of the GSSD case study, which raised the importance of institutional and organizational barriers to IT implementation and the design of IT strategies to address these barriers.

1.4 Thesis Outline

This thesis begins with a literature review on studies to date which have examined the impact of IT on development. First, common weaknesses in these studies are identified. Second, these findings are then incorporated into a conceptual framework that articulates the positive and negative linkages between IT and sustainability, with examples that illustrate the linkages. Third, the GSSD case study is examined in detail to assess the implications of IT for addressing sustainability challenges. The technical evolution of GSSD into a more sophisticated application is examined in considerable detail. This effort results in some specific conclusions regarding the flexibility and robustness of IT advances for addressing increasingly complex, global issues, such as those related to sustainable development. Finally, the study concludes by integrating the main findings of this research into a new methodology for addressing the linkages between IT and sustainability.

2. IT and Sustainable Development: A Literature Review

2.1 Introduction

Until a few years ago, the majority of the literature on the impacts of IT on development was focused on industrialized countries. For example, the Organization for Economic Cooperation and Development (OECD) web site alone has approximately 600 different reports, case studies, and other documents, mostly focused on IT efforts in the advanced OECD countries[8]. In contrast, the World Bank, which has conducted one of the most substantial efforts on the sustainable development of developing countries, has approximately 25 reports examining various aspects of IT and development in the developing world[9].

Overall, the majority of studies on both developing and developed countries exhibit similar shortcomings:

- The majority of efforts have focused on physical infrastructure and connectivity, resulting in insufficient attention to users, content, and the relevance of non-technical factors to leveraging IT for sustainability;
- Analyses are relatively theory-free;
- Studies are generally non-empirical and prescriptive in nature; and
- Research has been overwhelmingly singular in focus, with very little effort to develop integrated or holistic approaches to understanding issues in IT and development.

The following sections provide more detail on the nature of the major studies, their performance to date, and their implications. On this basis, we illustrate how critical gaps in this literature are posing significant barriers to a comprehensive understanding of the linkages between IT and sustainability.

2.2 Major Studies on IT and Development

2.2.1 Overview

For the perspective on industrialized countries, major reports have been produced by the United States, the European Union countries, and OECD. Reports on IT impacts on the developing

[8] See OECD's Information and Communication Technologies web site at: http://www.oecd.org/EN/documentation/0,,EN-documentation-13-nodirectorate-no-no-no-13,00.html .
[9] See World Bank's Global Information and Communication Technologies web site at: http://lnweb18.worldbank.org/ict/resources.nsf/InfoResources?OpenView .

world have been completed mainly by international and inter-governmental institutions, such as the World Bank and the United Nations (U.N.).

2.2.2 Reports by the United States, European Union, and OECD

The United States government has produced a large number of reports related to the impacts of IT on the country's development. For example, the United States Department of Commerce provides an annual report on the "digital economy[10]" and regular reports on the "digital divide[11]" in the U.S. While these reports provide plenty of economic and social data related to IT and the "new economy," there is no discussion of the broader implications of these findings on sustainable development in the U.S., not even in the most recent versions of these reports. Moreover, although certain potential negative linkages are identified, such as "digital divide" effects, there is no mention of other potentially significant negative impacts, such as environmental rebound effects due to the intensified use of IT products and services.

Figure 2.1 below illustrates a recurring feature of digital divide reports: reliance on physical indicators for assessing the extent of the digital divide. In other words, these reports consistently define one of the most significant negative linkages, the "digital divide," in purely physical terms.

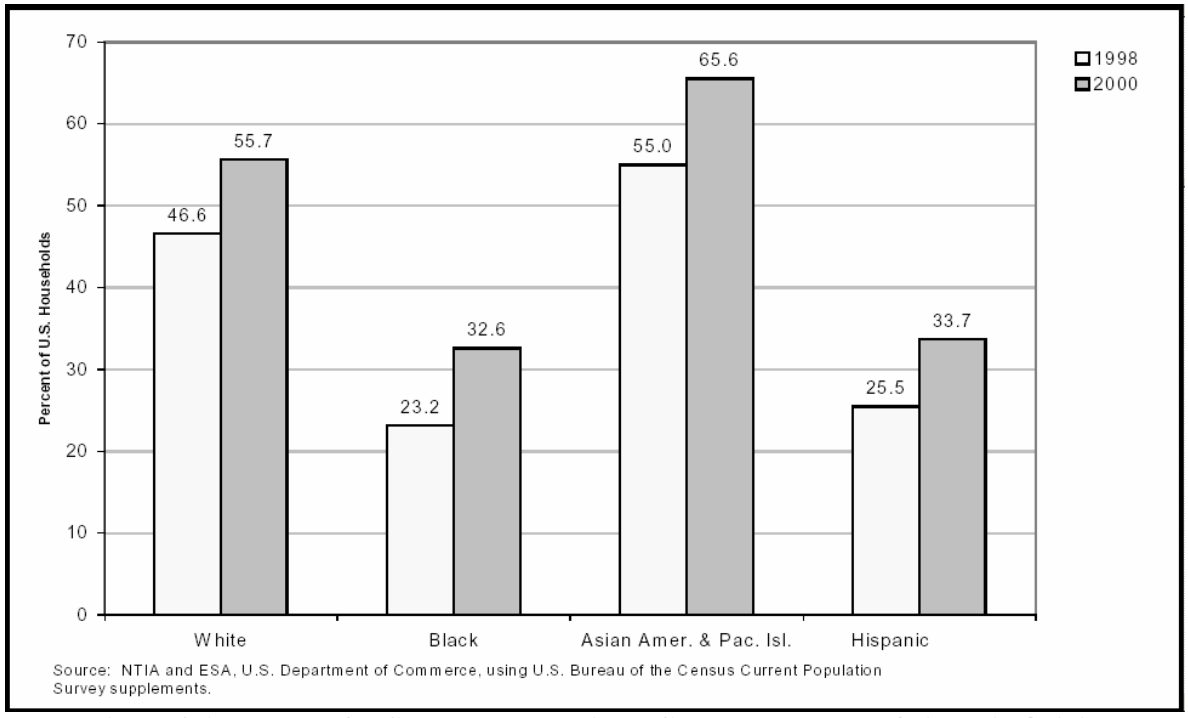


Figure 2.1 Percent of U.S. Households with a Computer By Race/Hispanic Origin
Source: United States Department of Commerce (2000b)

[10] United States Department of Commerce (2002), (2000a), (1999a), (1998a).
[11] United States Department of Commerce (2000b), (1999b), (1998b), (1995).

Figure 2.1 shows that progress has been made with all racial segments of the U.S. population in terms of computer ownership. However, the figure does not provide any information on the extent to which the minority groups have been given access to more knowledge as a result. The reduction of non-technical barriers, such as the ability to access content and build capacity, are equally important considerations as connectivity. Nevertheless, these issues are not addressed in these reports, and as a result, relevant indicators are not presented.

In addition to the U.S., the European Union (E.U.) has been very active at developing policies relevant to the emerging "information society," which is the term used by the E.U. to refer to the new societal and economic conditions brought about by the IT revolution. The European Commission has developed an Information Society website, whose aim is to: increase "public awareness and understanding of the potential impact of the Information Society and its new applications throughout Europe," optimize "the socio-economic benefits of the Information Society in Europe," and enhance "Europe's role and visibility within the global dimension of the Information Society[12]."

This program has developed substantial policy statements regarding the role of IT in Europe's development. However, there has been little emphasis on research or analytical approaches to assessing potential policy pathways. For example, the web site mostly offers general policy statements regarding Europe's recommended IT strategies. While there are some case studies and reports documented, there is no attempt to explore the implications of these results further, or to leverage them by developing a more integrated framework for understanding the impacts of IT on development. In other words, this program illustrates a common weakness among many European efforts to date: there is little attempt to integrate various issues related to IT and sustainability into a coherent model for understanding the positive and negative linkages associated with IT and sustainability.

One recent initiative that attempts to remedy this issue is the Digital Europe[13] program, which has been undertaken by the European Union to examine the interplay between IT, with a focus on eBusiness, and sustainable development. This project began in July 2001 and has since produced a literature review[14] and several research documents[15] related to eBusiness and sustainability. The literature review report is effective at demonstrating the potentially negative role of IT in environmental sustainability via rebound effects (such as an increase in energy and material consumption), which is explained in more detail in section 3 of this thesis. In addition, the program develops a framework of analysis based on the following themes relevant to sustainability and eBusiness:

- Inclusion in the digital society
- Social change
- Dematerialisation of products and services
- Transport and mobility

[12] European Commission Information Society web site: http://europa.eu.int/information_society/basics/aboutus/index_en.htm .
[13] Digital Europe web site: http://www.digital-eu.org/default.asp .
[14] Digital Europe (2001).
[15] See http://www.digital-eu.org/themes/default.asp for more information.

- Regional development and cohesion (digital divide among countries in Europe)
- Corporate social responsibility in the digital society

As a result, this report offers a good first attempt at an integrated approach to understanding the effects of eBusiness on sustainability. The cross-cutting themes presented in this report will be further examined through case studies, surveys, and interviews of major eBusiness players in Europe, such as AOL Europe, Barclays Bank, and Hewlett Packard[16]. While this study only focuses on the eBusiness aspects of IT, the findings of this research will likely provide valuable insights once the report is completed and issued in July 2003[17].

As mentioned earlier, the OECD has also been one of the most active contributors to the literature related to the socio-economic implications of the IT revolution on the industrialized countries. The OECD reports provide a vast amount of empirical data on IT and related socio-economic indicators, covering topics such as IT use and access, eBusiness, eEducation, eGovernment, and the IT sector. However, the majority of the data collected applies to OECD countries only. While the data potentially provides valuable knowledge regarding best practices and experiences in the industrialized world, it nevertheless limits the scope of analysis relevant to IT and development in the developing world.

One of OECD's most established reports is the annual "Information Technology Outlook." The most recent issue[18] finds that IT continues to play an increasingly important role in industrialized economies, despite the continuing period of economic downturn that was initiated in 2000. Another important finding is that there is still a clear digital divide among OECD countries, as illustrated in Figure 2.2.

[16] For an example of private sector efforts to understand these issues, see British Telecom (2001).
[17] The project timeline is provided at: http://www.digital-eu.org/aboutus/default.asp?pageid=49 .
[18] OECD (2002).

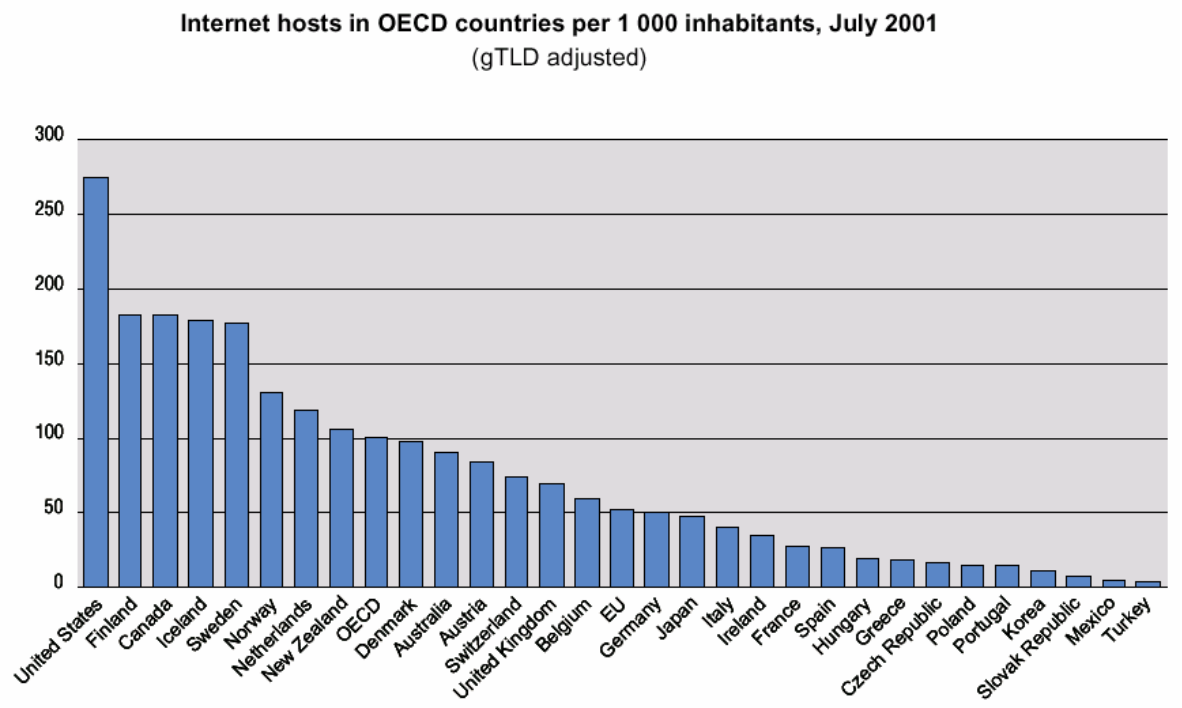


Figure 2.2 Internet Hosts in OECD Countries, 2001
Source: OECD (2002)

In addition to the IT reports, OECD also has a series of reports devoted to sustainable development issues[19]. However, with a few exceptions, there is very little discussion of IT prospects in the sustainable development reports. OECD did recently produce a report on the impacts of IT on environmental sustainability[20], which examines issues very similar to those presented in the Digital Europe study[21]. The report focuses on direct environmental effects of IT production and use, as well as the more uncertain indirect, also known as rebound, effects. Overall, this report supplements the more thorough discussion provided by the Digital Europe study on environmental impacts of IT.

2.2.3 Reports by International Institutions

To date, the most substantial literature on issues related to IT and development in the developing world has been produced by international institutions such as the World Bank and the U.N. There are a number of programs that have been established within these institutions that focus on these issues. For example, the overall aim of the World Bank's infoDev[22] program is to promote the use, application, and development of IT for economic and social advancement. This program provides grants and other incentive programs to encourage IT adoption in developing countries.

[19] See http://www.oecd.org/EN/home/0,,EN-home-21-nodirectorate-no-no--21,00.html .
[20] OECD (2001).
[21] Digital Europe (2001).
[22] See http://www.infodev.org/ .

As a result, the program has developed a series of project reports, case studies, and working papers related to various aspects of IT and development.

The World Bank's efforts to advance IT capabilities in the developing world is based on the following premise: a focus on IT development and innovation will help developing countries address the obstacles to sustainable development. Figure 2.3 summarizes the logic espoused by the World Bank. In other words, the World Bank supports IT projects in developing countries because they believe that the IT revolution is:

- Having a radical impact on the industrialized world;
- Presenting tremendous opportunities for the developing world;
- Posing significant threats to the developing world;
- Raising the need for investment and policies that will help advance IT initiatives in the developing world.

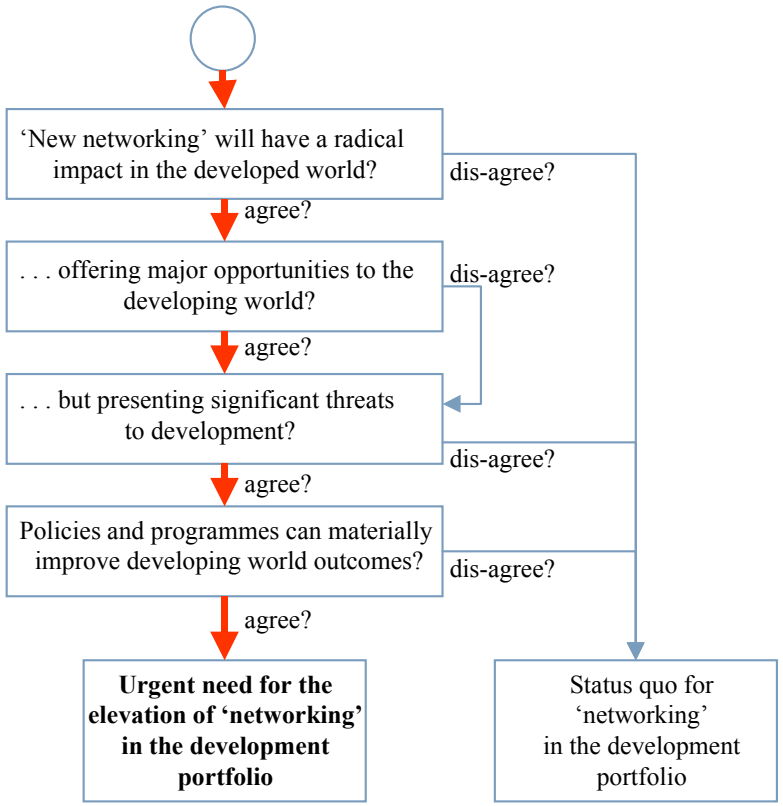


Figure 2.3 World Bank's Logic for Supporting IT Projects in the Developing World[23]
Source: World Bank (2000c)

[23] The term "networking" in this context is used by the World Bank to refer to information, communication, and the relevant technologies. They deliberately use this term instead of IT in an effort to emphasize the importance of linking individuals, organizations, locations, and systems, and the flow of information over these links.

The United Nations Sustainable Development Networking Programme[24] (SDNP) is similar to the World Bank's infoDev program, both in emphasis and scope. As an outgrowth of the Earth Summit, the SDNP offers assistance to developing countries in establishing connectivity to national networks and the Internet, developing online content, and training managers and users of the networks.

While both the SDNP and infoDev programs provide plenty of reports highlighting the major issues faced by developing countries and collect data and case study information on their projects, neither program has yet to provide comprehensive and useful documentation on the results of their efforts so far. For example, while many case studies have been generated over the past few years, there has not been an adequate emphasis on cross-country comparisons. In addition, there has not yet been a streamlined effort to gather and disseminate best cases in IT for sustainability, even though both institutions have a lot of material from which to develop such valuable resources. Therefore, while the World Bank and U.N. studies have been very informative and effective at presenting the pressing issues of concern in developing countries, they have not yet leveraged the wealth of data and case studies at their disposal to provide any truly robust recommendations or analyses that could be used by countries who are trying to develop IT strategies to meet their sustainable development goals.

The U.N. also has several other programs devoted to IT and development, including Info21[25] and the ICT Task Force[26]. Similar to the InfoDev and SNDP programs, these initiatives have mostly issued major policy statements and anecdotal reports of various IT initiatives. However, the Digital Opportunity Initiative (DOI)[27], a public-private partnership of the United Nations Development Programme (UNDP), Accenture, and the Markle Foundation that was launched at the G-8 Okinawa Summit in 2000, has produced some promising work that stands apart from other U.N. efforts.

In a recent report, the DOI presents an interesting hypothesis that "a development-focused ICT strategy that leverages the powerful synergies of ICT as an enabler of social and economic development can lead to the creation of a ***development dynamic***[28]" (emphasis added). As illustrated in Figure 2.4, the development dynamic framework is composed of five interrelated areas of focus for IT strategy: policy, infrastructure, enterprise, human capacity, and content and applications, all of which rely on various forms of collaboration and leadership for success.

[24] See http://www.sdnp.undp.org/ .
[25] See http://www.undp.org/info21/ .
[26] See http://www.unicttaskforce.org/ .
[27] See http://www.opt-init.org/ .
[28] Digital Opportunity Initiative (2001), p.33.

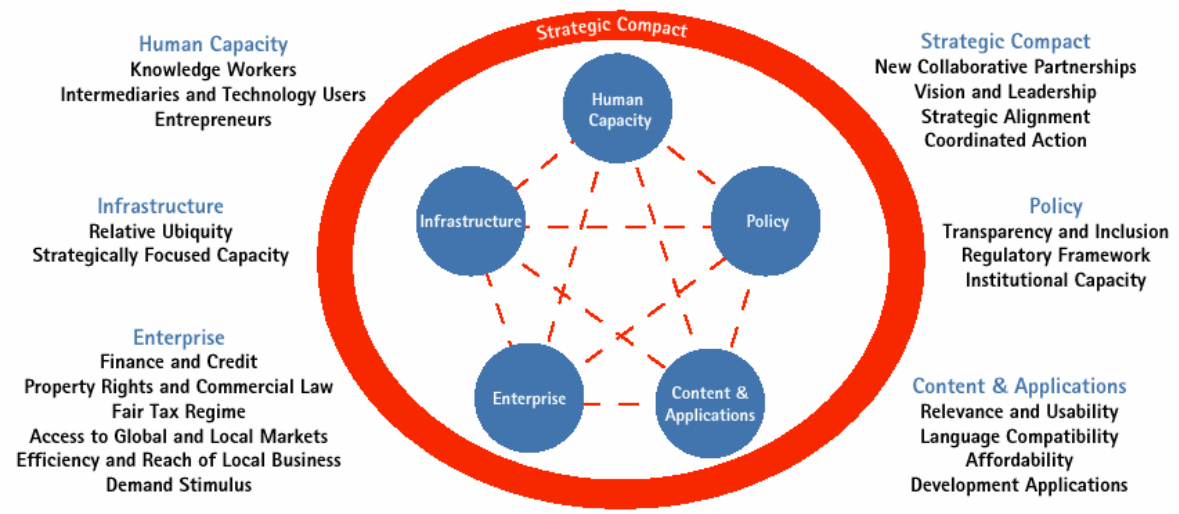


Figure 2.4 Development Dynamic Framework
Source: Digital Opportunity Initiative (2001)

Since these areas are interrelated, DOI argues that strategic interventions over multiple component areas can generate returns to scale much greater than those achieved by a concentrated focus in any single area, due to "feedback, multiplier and network effects," which can "ignite a virtuous cycle of sustainable development." The systems approach developed in the DOI report is a significant contribution to the IT and development literature. Hopefully, this study marks the beginning of an important departure away from the traditional prescriptive approach employed by international institutions and evolving towards more holistic, integrated, and rigorous analyses of the complex issues related to IT and sustainability in the developing world.

2.3 Summary

This section provides an overview of existing literature devoted to IT and sustainable development. These efforts have been successful at providing anecdotal, broad-based, and prescriptive information on IT impacts on development. Nevertheless, there are critical gaps in this literature which prevent a comprehensive understanding of the linkages between IT and sustainability. For example, these studies fail to include:

- An integrated or holistic framework for understanding issues in IT and development;
- Theoretical approaches to assessing the linkages between IT and sustainable development;
- Consideration of significant non-physical factors to leveraging IT for sustainability; and
- Coherent recommendations based on thorough analyses of case studies and other empirical findings.

The remaining sections of this thesis help to address these gaps by:

- Providing an integrated framework for approaching issues related to IT and sustainability;
- Developing a theoretical approach based on positive and negative linkages between IT and sustainable development;
- Incorporating the significance of non-physical factors, such as institutional and organizational constraints, in assessing the success of IT projects for sustainability; and
- Analyzing a relevant case study (Global System for Sustainable Development) and developing recommendations for future IT efforts devoted to sustainability issues.

3. IT and Sustainable Development: Negative Linkages

3.1 Introduction

As discussed in the previous section, the literature devoted to IT and sustainability has largely been singular in focus, devoting analyses to only a particular area of development. Furthermore, much of the literature summarized above largely overlooks the potential for negative linkages associated with IT and sustainable development. In other words, it does not consider the possibility that IT applications may, in effect, hinder rather than support efforts to achieve sustainability goals. The following discussion attempts to remedy these shortcomings by providing a holistic examination of how IT can have a detrimental impact on sustainable development. These negative aspects are critical to the success of policies aimed at leveraging IT for development.

3.2 Over-Reliance on IT for Addressing Conceptual Ambiguity

A common and inaccurate view of IT tools and capabilities is that they replace the "hard work" required by humans to create and bound the conceptual framework underlying the implementation of an IT-based solution. For example, as described in Section 2, although there are many ongoing projects, supported by the UNDP, World Bank, OECD, and others, aimed at implementing IT projects for sustainable development, these projects are often designed without a clear framework of sustainability and a systematic approach explaining how IT initiatives will approach specific goals related to sustainable development. As described in Section 1.1, this can be largely attributed to the differing definitions of sustainable development. Although IT can contribute (as a tool) to refining the conceptual model, the initial human-driven mental work is itself a necessary and essential component to designing IT initiatives in support of sustainability.

3.3 Decrease in Information Quality

The IT revolution, particularly the advances in the Internet, has enabled tremendous growth in the quantity of all types of information. However, the consistent growth seen in the ***quantity*** of information has not translated into an increase in the overall ***quality*** of information available via the Internet. In fact, some may argue that the overall quality of information has unavoidably decreased, due to a "dilution" effect caused by a wide range of information sources and the unreliability of many of these sources. Information that is provided by IT tools and services is often automatically assumed to be usable, even reliable, when the reverse is more likely the case. This trend has potentially serious implications for utilizing IT for sustainable development, because projects could be relying on unsound information for guidance.

3.4 Environmental Rebound Effects

One of the most significant detrimental effects of IT on sustainable development can be broadly classified as "rebound effects." An environmental rebound effect is a trend that emerges to counteract the energy, resource, and pollution reductions gained by IT production or use. Harmful rebound effects potentially occur when the widespread consumption of these products result in harmful environmental impacts that offset the initial resource savings. These effects are usually classified as primary or secondary. Primary effects are direct environmental impacts due to the production and use of IT infrastructure. Secondary effects are environmental impacts that arise due to IT-induced changes in consumer behavior. These negative linkages are discussed further in the following section.

3.4.1 Primary Effects

Waste

At a first glance, IT products seem to result in less production of waste than more traditional products. However, a closer look at the issue reveals that this is not always the case. Due to shorter innovation cycles, many IT products have shorter life spans, leading to an increasing amount of waste electrical and electronic equipment (WEEE). For the last 10 years, an annual conference sponsored by the Institute of Electrical and Electronics Engineers (IEEE), entitled "Electronics and the Environment[29]," has been devoted entirely to this issue. Furthermore, many IT products contain substances that are hazardous to the environment and human health, such as halogen-organic compounds and heavy metals, and are difficult to dispose of, recycle, or reuse. Many of the older IT products are still largely incinerated or landfilled, and the rest are largely recycled rather than reused.

Energy

There are potentially significant rebound effects from energy consumption due to IT use. For example, one study on book purchasing in Japan found that B2C e-commerce consumes slightly more energy than traditional retailing[30]. The life cycle assessment found that the additional energy requirements mainly stem from the additional individual packaging and transportation required to deliver online book orders. However, this study found that, even though consumers who shop online at home end up increasing their home energy consumption, energy consumption per book sold was slightly higher for traditional retail book stores than for the e-commerce option, which requires less building space and lower energy use for operations. Nevertheless, the energy analysis found the net energy use to be slightly higher for online bookstores, after accounting for packaging, transportation from publisher to bookstore/home, consumer travel to/from bookstore, and energy consumption at bookstore/home[31].

[29] For example, see Institute of Electrical and Electronics Engineers (2002).
[30] Williams (2002).
[31] Williams (2002).

As reported in one study, it is important to recall that "every piece of equipment that comprises the information economy has two connections- one for bits, and one for kilowatt-hours.[32]" This study estimates that the Internet was responsible for 8% of total electricity consumption in the U.S. in 1999[33]. With the U.S. electric grid being 56% coal fired, the study concluded that it would take approximately 1 pound of coal to move 2 MB across the Internet. It also estimates that the Internet contributed 50% to 66% of growth in electricity demand in the 1990s. It is important to note that the major source of electricity consumption is the equipment used to access and operate the Internet, as opposed to the actual Internet use[34]. The trend of round-the-clock operation of IT processes is becoming more common, due to growing consumer needs in areas such as online retail and banking. Furthermore, when non-networked, stand-alone computer equipment is included in the calculation, the study estimates that total electricity demand for IT accounts for approximately 13% of all electricity consumption in the U.S[35].

Some of the calculations and assumptions used in this study have been challenged by other analysts[36]. Some argue that the estimates for energy consumption of different types of IT equipment are overestimated. Regardless of the actual numbers, the energy implications of IT are an important area of study. For example, as more people become connected to the Internet, whether it be by PC, mobile phone, or personal digital assistant (PDA), the demand for bandwidth will continue to increase. This translates into growing demand for more equipment and hence more energy to drive this equipment- this is a serious implication of IT that requires serious consideration.

3.4.2 Secondary Effects

Other indirect effects, known as secondary rebound effects, arise from increased consumption of new IT products and services, and other changes in consumer behavior, which could outweigh IT's direct benefits.

Waste

The IT revolution has not lived up to its promise of creating the "paperless office." In fact, IT advances have led to increased paper consumption. Global consumption increased twenty-fold during the 20th century, and by a factor of three just during the last three decades[37]. One major factor is the increased accessibility to printers, which fuel the demand for paper. Email also contributes to increased consumption. According to one source, an organization that uses email sees an average 40% increase in paper consumption as a result[38].

[32] Mills (1999), p.100.
[33] Ibid, p.93.
[34] Ibid, p.98.
[35] Ibid, p.109.
[36] For example, see Romm (1999), Koomey et al. (1999).
[37] Robins et al (1996).
[38] Sellen et al (2001).

The boom in Internet commerce also has potential implications for growing package waste. As the process for overnight shipping improves and becomes more convenient, the sizes of packaged orders will also grow smaller, thereby leading to greater package waste. This trend could eventually offset the initial resource savings of purchasing goods online.

Transportation-related Pollution

Although there are many ways in which IT may reduce the need for transportation, there are also IT-related services that could induce more transportation with worse-than-intended environmental consequences. For example, online commerce has increased the demand for overnight shipping, which has generated more freight traffic, both in the air and on the ground. Due to the reach of the Internet, there is also a growing trend towards global shipping, resulting in geographically extended supply patterns. These new transportation demands have potential environmental implications that need to be assessed.

Transportation demands are also growing due to changing consumer behavior. Long-distance and leisure travel is increasing, due to a need to establish face to face contact between dispersed people who have been connected via the Internet.

3.5 Economic Dependence

Another significant negative linkage between IT and sustainable development is related to the over-dependence on IT for economic prosperity. In other words, a diversified economy that relies on other non-IT related goods is still a necessary requisite for sustainable development.

The "bubble burst" of 2000 is a solid example of this potentially harmful linkage. In 2000, after several years of "inflating," the "dotcom bubble" finally burst, largely due to unrealistic expectations for entrepreneurial opportunities in IT. In the latter part of the 1990s, stock prices of IT companies, many of which had yet to yield any profits, were extremely overpriced. When it became apparent that financial returns from these companies would be much lower than anticipated, the "bubble" burst in 2000. Figure 3.1 shows the historical stock chart for Amazon.com. As shown by the figure, at the peak of the dotcom fervor, Amazon's stock exceeded $100 per share (after several stock splits), even though the company had yet to generate a profit. In fact, Amazon just generated its first profit ever in the fourth quarter of 2001[39].

[39] http://news.zdnet.co.uk/story/0,,t286-s2102938,00.html .

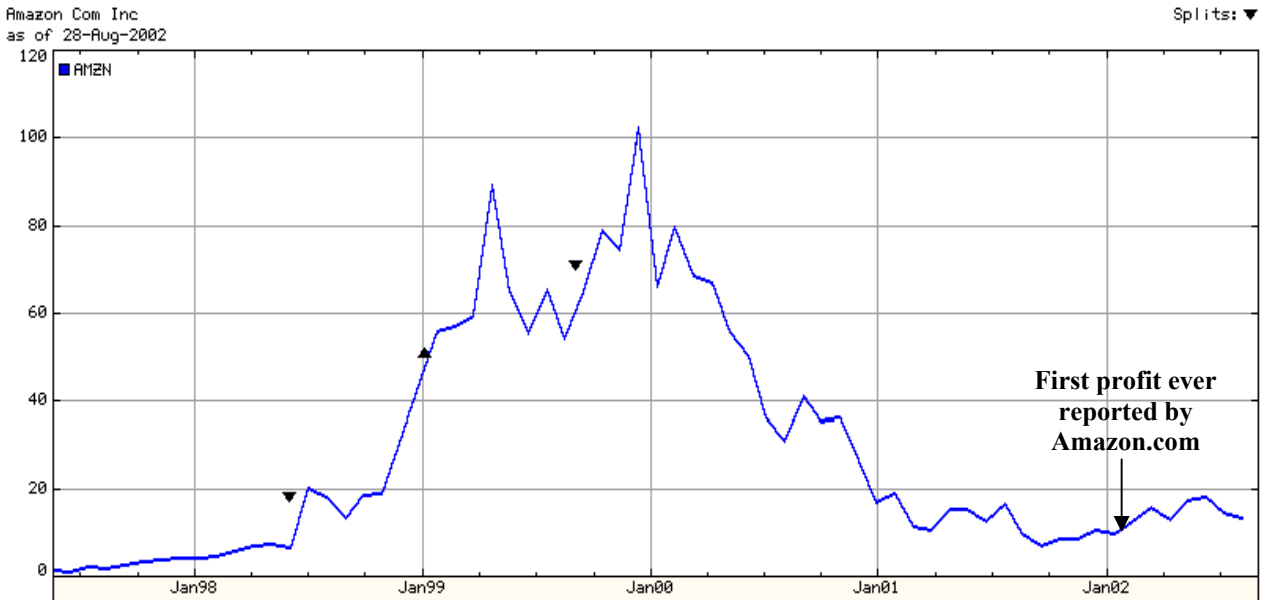


Figure 3.1 Stock History for Amazon.com
Source: Yahoo Finance (**http://finance.yahoo.com**)

The bubble burst had a destabilizing effect on economies all over the world. As shown in Figure 3.2, the year 2000 marked the beginning of a rapid deceleration in GDP growth for both industrial and developing countries. Since the sharp economic downturn preceded the terrorist attacks of September 2001, the attacks only reinforced the global economic decline, rather than serve as the primary cause of the downturn.

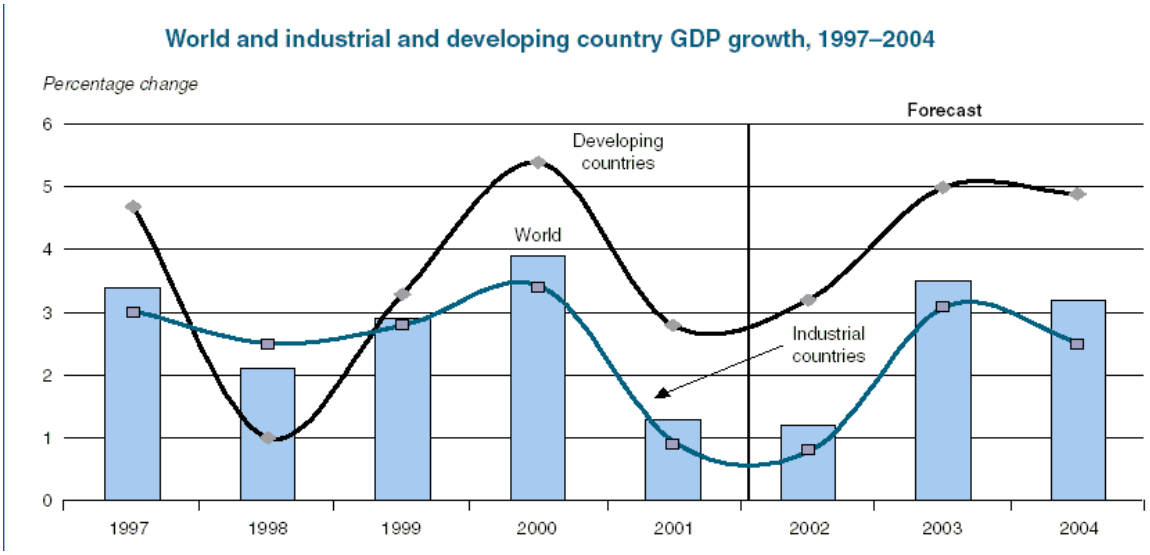
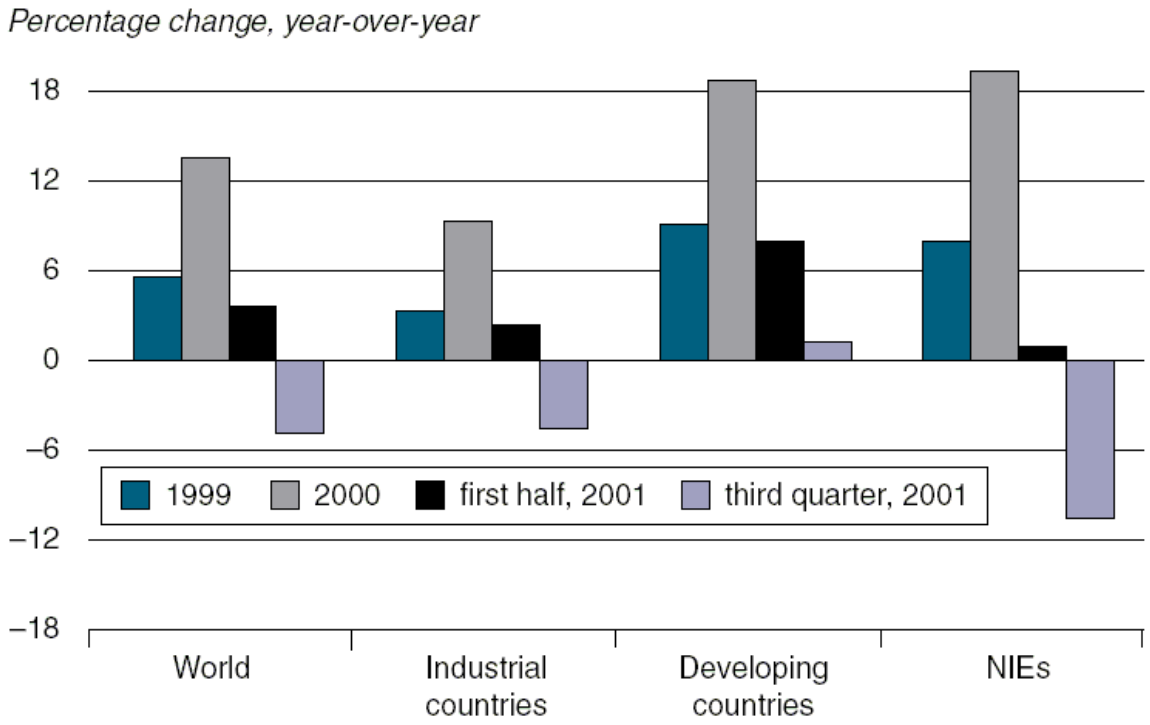


Figure 3.2 GDP Decline after "Bubble Burst"
Source: World Bank (2002a)

The collapse of the high-tech sector also led to a record deceleration in merchandise trade growth around the world. Figure 3.3 shows that East Asian newly industrialized economies (NIEs), such as Hong Kong, Singapore, and Taiwan, who are heavily dependent on IT-based merchandise exports, suffered more from this economic downturn than the rest of the world.



Note: Exports are for a sample of countries representing 79 percent of world exports.

Figure 3.3 Impact of the "Bubble Burst" on World Export Growth
Source: World Bank (2002a)

In summary, while the IT revolution helped to stimulate many economies in the industrialized and developing economies alike, it also contributed to an economic over-dependence on IT, which had disastrous consequences when the IT market began to suffer in 2000. Therefore, the implementation of diversified economic plans, which balance the focus between IT and more traditional markets and assets, represent a key and necessary strategy to leveraging IT for sustainable development.

3.6 "Digital" and "Knowledge" Divides

3.6.1 Introduction

Contrary to a widely held belief that the benefits of the IT revolution have global dimensions, the gap between developed and developing countries in the "digital divide" is still considered to be widening. It is currently estimated that developed countries account for 90% of global IT spending and 80% of all Internet users[40]. These numbers paint a stark picture for IT diffusion in developing countries. More importantly, since IT has become instrumental to knowledge accumulation, the "digital divide" has also caused a "knowledge divide," or a knowledge gap between developed and developing countries, which is also on the rise due to the IT advancements primarily utilized by developed countries.

As Figure 3.4 illustrates, only approximately 361 million people, equivalent to about 6% of the world's population, are connected to the Internet. In addition to this glaring evidence of a "digital" and "knowledge" divide, there are other revealing indicators, such as income distribution. Approximately 74% of all Internet users are in the highest income level, even though they only constitute 15% of the total world population. In addition to income, disparities in IT access and use can be seen across lines of education, race, gender, and language, among other factors.

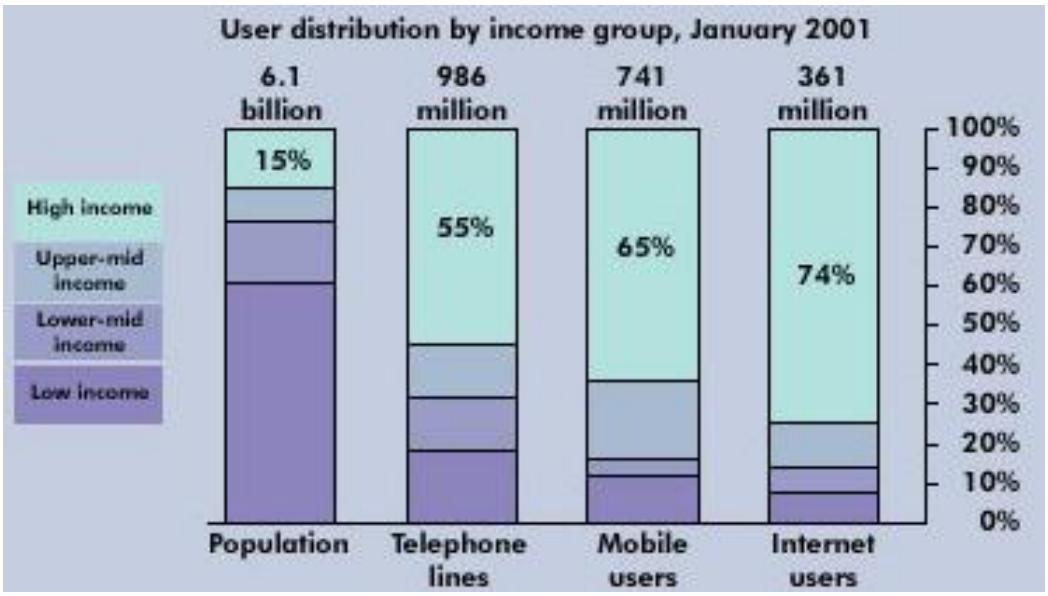


Figure 3.4 Income Distribution of Telephone, Mobile, and Internet Users
Source: International Telecommunications Union (2002)

[40] The Economist (2000).

While it's true that all countries, even the poorest, are increasing their IT access and use, the richer countries are utilizing IT at such an exponential rate that the "digital" and "knowledge" divides between countries is actually growing, resulting in significantly greater per capita use of IT in industrialized countries compared to developing nations[41].

3.6.2 Physical Barriers

Although the "knowledge divide" debate, and the non-physical factors related to IT use, is slowly gaining more attention, access to physical infrastructure remains an important, and very real, issue for many developing countries. Therefore, the opportunities provided by the IT revolution to developing countries have been offset by the physical requirements needed to leverage IT effectively. As a result, industrialized countries have been able to advance further due to the infrastructures that were already in place for leveraging IT applications. Figure 3.5 illustrates the incredible gap in IT infrastructure investments between OECD countries and the rest of the world. This figure demonstrates that the physical IT investment gap is still very much a significant component of the "digital divide."

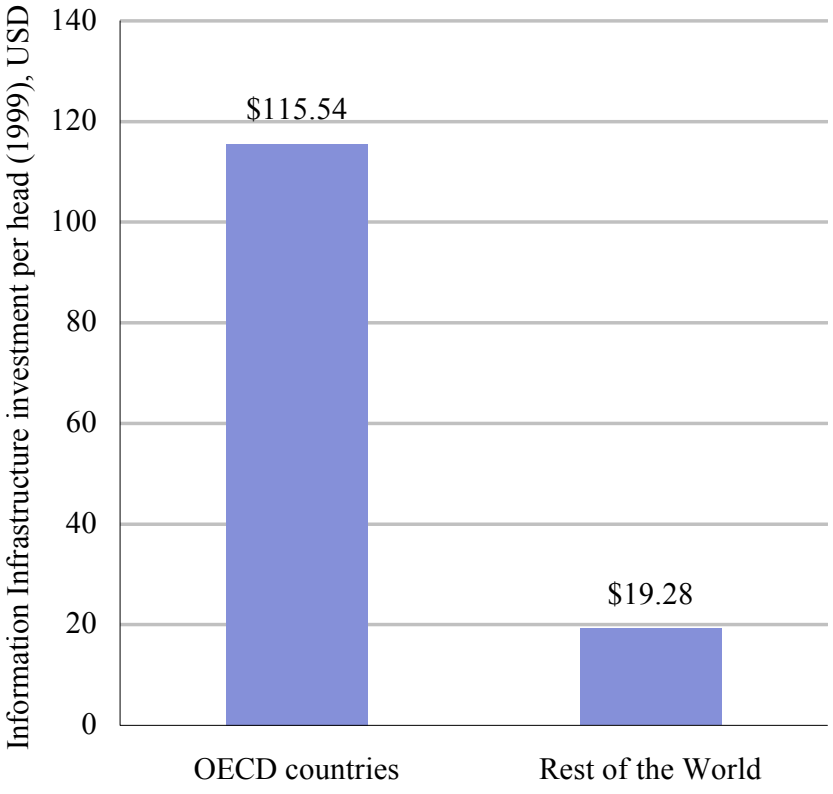


Figure 3.5 IT Infrastructure Investment Per Capita, 1999
Source: World Bank (2000c)

[41] Bridges.org.

3.6.3 Knowledge Barriers

As the costs for physical IT infrastructure continue to decline, addressing the knowledge barriers becomes more and more critical to sustainable development. Once the physical barriers are addressed, there are still a set of knowledge-related challenges that still restrict the full leveraging of IT capabilities. Several examples are provided below.

3.6.3.1 Lack of Multilingual Support

Due to various reasons, the English language dominates the content distributed over the Internet and the user interfaces of IT applications in general. As a result, the predominantly non-English speaking world is unable to utilize these tools for their benefit. Since sustainability challenges are globally distributed, a large portion of the world will be at a disadvantage by not being able to utilize IT advances for sustainable development.

3.6.3.2 Dearth of Local Knowledge

Many local efforts to address various sustainability issues provide valuable guidance and knowledge for other similar initiatives elsewhere in the region and the world. However, due to a lack of available tools for knowledge provision, this information is not available to a wide audience. As a result, many local efforts often repeat mistakes, or miss opportunities, that were experienced in other successful and related initiatives. This is especially critical to developing areas. By only having access to efforts in more advanced countries, local projects in developing countries have difficulty replicating such efforts since they operate under significantly different social and economic conditions.

3.6.3.3 Limited Search Capabilities

As noted before, sustainability challenges are diverse and require various types of information. Unfortunately, most IT tools are unable to accommodate diverse users with various information needs. This problem is also linked to the information quality issue raised in section 3.3. To gain access to a quality-controlled and indexed search tool, users often have to pay a premium, which again excludes many people in the developing world who could benefit from intelligent search capabilities.

3.7 Summary

The preceding discussion illustrates the importance of considering potentially negative linkages associated with IT and sustainable development. This perspective is essential for considering the feasibility of IT applications for sustainability because it contributes to a more holistic approach

that ensures that the positive attributes of IT, as discussed in the following section, are leveraged while detrimental impacts to sustainable development are prevented or addressed.

4. IT and Sustainable Development: Positive Linkages

4.1 Introduction

As is evident by the literature reviewed in Section 2, there are many studies that have argued that IT can contribute significantly to sustainable development goals. However, there have been very few attempts to examine this premise in a holistic manner. Sections 3 and 4 together represent a comprehensive and integrated approach to understanding the benefits and detriments associated with IT use for sustainability. This section focuses on the positive attributes of IT and concludes with one of the more neglected, but potentially powerful, positive linkages: IT as an enabler of knowledge networking.

4.2 Waste Minimization

Waste minimization, or dematerialization, can be defined as achieving material and energy reduction per unit of product or service produced. In the context of IT, it often involves the conversion of atoms to bits, a phenomenon explored in detail by scholars such as Nicholas Negroponte of the MIT Media Laboratory[42]. One of the more profound examples in IT is the substitution of services for physical products, with the introduction of services such as voice mail to replace physical machines. The Swedish telecommunications company Telia conducted a life cycle comparison of their Telesvar voice mail service with traditional answering machines, and found that voice mail services resulted in a 20-fold waste reduction, with decreases in power consumption and greenhouse gas emissions by a factor of 230 and 240, respectively[43].

Another dramatic IT example involves the dematerialization of hardware. As shown in Figure 4.1, Moore's Law demonstrates that the number of transistors per square inch on integrated circuits doubles every 18 months. This laws still holds true today, and Intel Corporation, the leading manufacturer of integrated circuits, believes that the trend will continue for at least another decade[44]. In other words, the performance of IT equipment will continue to improve without imposing additional demands on materials and energy, and resulting in significant cost savings for many businesses. This is one example of how IT may be considered to have a positive impact on sustainable development. However, it is important to note that there still may be rebound effects that could overcome these resource savings, as discussed in section 3.

[42] Negroponte (1995).
[43] Global e-Sustainability Initiative (2002), p.31.
[44] See http://www.intel.com/research/silicon/mooreslaw.htm .

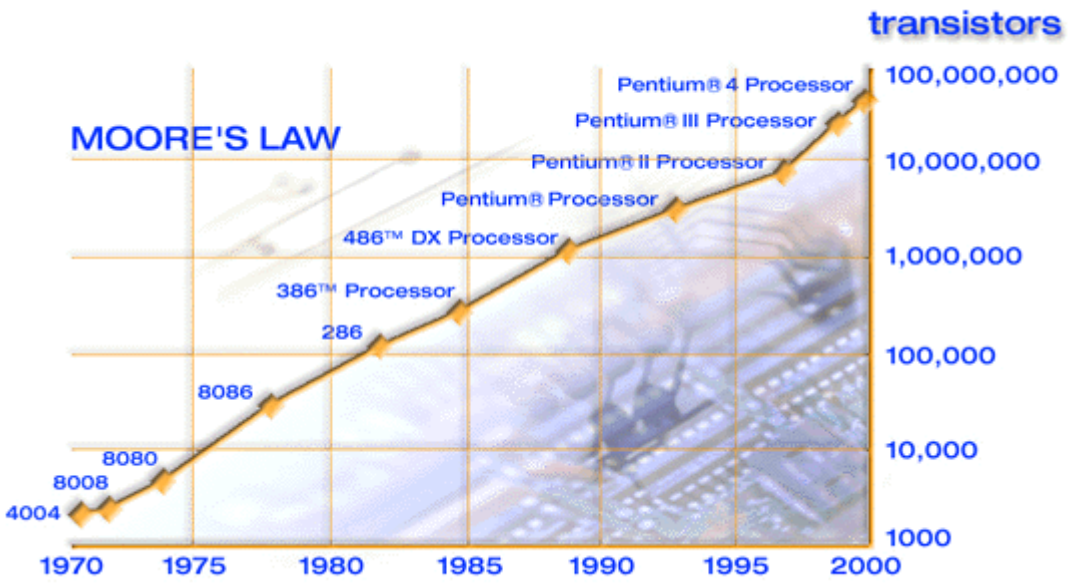


Figure 4.1 Dematerialization by Moore's Law
Source: Intel Corporation (2002)

IT also helps to promote material reuse through the exchanges and auction sites on the Internet. On the consumer side, eBay and other auction web sites have been wildly popular. On the business side, a significant industrial secondary market has been established on the Internet. Buyers of industrial products, particularly metals, are now able to buy materials from all over the world cost-effectively through online exchanges.

4.3 Energy Savings

Energy intensity, defined as energy consumption relative to GDP, is an indicator that is commonly used to measure progress in energy efficiency. As shown in Figure 4.2, in the United States, energy intensity has declined steadily since the 1970s, with a more dramatic drop in intensity since the late 1990s.

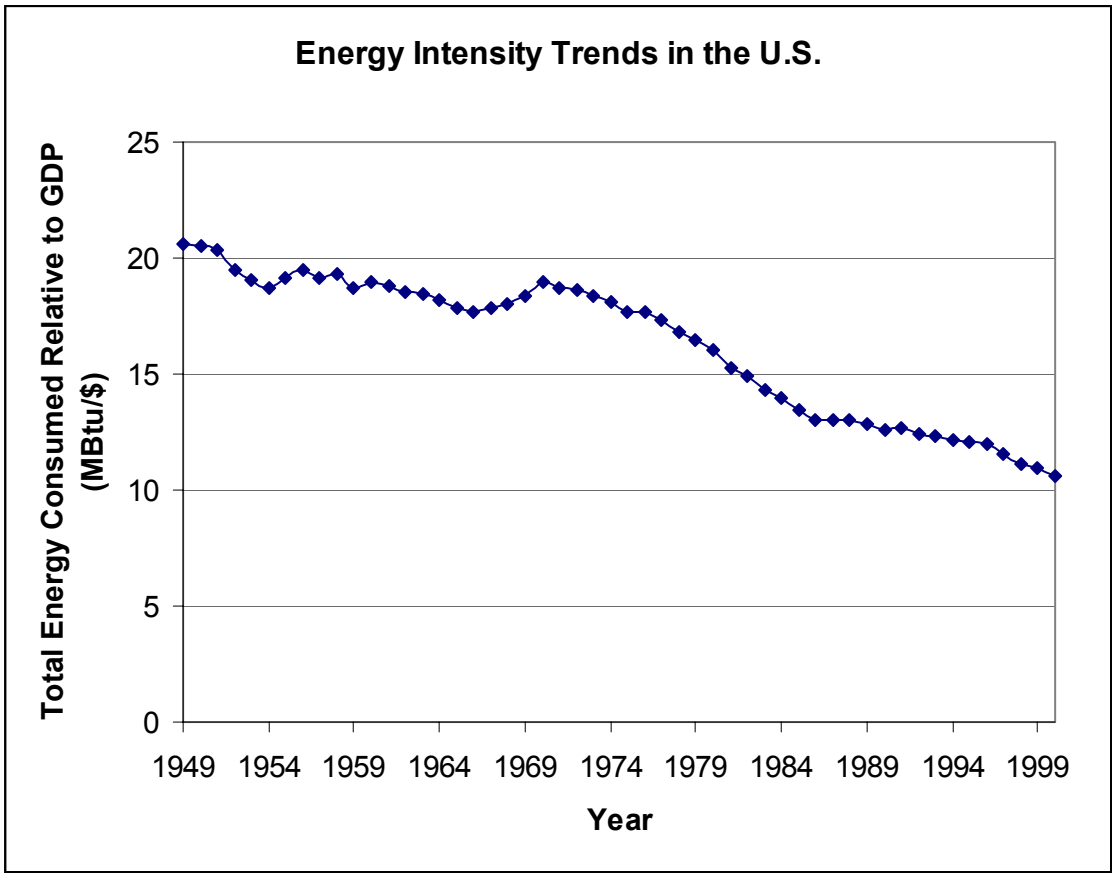


Figure 4.2 Energy Intensity Trends in the U.S.
Source: U.S. Energy Information Administration (2000)

In addition to general improved energy efficiency of processes and products, a significant portion of the recent decrease in energy intensity is also attributed to "structural" changes, which refer to improvements due to economic decline in energy-intensive sectors and growth in IT and other less energy-intensive industries[45]. When Figures 1.2 and 4.2 are examined in concert, it is clear that IT has contributed significantly to recent surges in productivity, and has also been a major factor in recent energy intensity improvements.

However, it is important to note that energy intensity serves as an indicator for energy efficiency, rather than energy consumption. In the climate change policy paper issued recently by the Bush administration[46], energy intensity was a significant part of the President's proposal to address climate change. However, this plan was met with plenty of criticism from many scientists and policy analysts[47], because energy intensity reductions can occur even when emissions of greenhouse gases increase, due to the gains in productivity. Therefore, energy intensity

[45] Romm (1999), p. 17.
[46] The Bush administration's global climate change policy book can be found at: http://www.whitehouse.gov/news/releases/2002/02/climatechange.html .
[47] For example, see http://www.nytimes.com/2002/02/26/science/earth/26CLIM.html or http://www.energyfoundation.org/national/NationalAnalysis.pdf .

reductions are often misinterpreted as a sign of environmental improvement, rather than more as an indicator of economic growth and productivity gains.

Sources of energy consumption can be generally divided into four sectors: residential, commercial, industrial, and transportation. The following discussion examines how IT affects energy consumption in these sectors.

Residential and commercial energy consumption occurs mainly in buildings. In the case of the U.S., buildings contribute to approximately 37% of all energy consumption, with residential consumption being only slightly higher than commercial use[48]. In the case of the commercial sector, IT, particularly e-commerce, has had a positive effect on energy conservation by replacing physical stores with virtual stores on the Internet. For tangible goods, there is still a need for warehouses, but inventories are often dramatically reduced and space is allocated more efficiently due to IT advances, thus contributing to increased energy efficiency. Based on a 1998 case study on Amazon.com, it has been estimated that commercial building energy consumption per book sold is up to 16 times higher for a traditional store versus an online store[49]. In addition to reducing the need for physical stores, IT is enabling more efficient supply chain management, resulting in inventory reduction, and substantial savings in materials handling, warehousing, and administrative costs.

Another factor in the reduction of building use is the increasing trend of teleworking, also known as telecommuting. IT advances have enabled businesses to provide more convenience and flexibility to their employees by allowing them to work remotely, often from home. For example, AT&T and IBM have implemented company-wide strategies to provide alternative workplaces for their employees, including teleworking options. Both companies estimate significant cost savings from these measures, due to reductions in square footage of commercial office space and energy consumption[50]. However, as discussed in section 3, energy consumption in homes needs to be examined as well, to make sure the commercial energy savings are not offset by increased residential usage.

As a result of all these factors, one report estimates that IT and the Internet Economy could result in as much as 3 billion square feet reduction in commercial building use in the U.S., which comprises approximately 5% of U.S. commercial floor space[51].

In the residential and commercial sectors, IT has also contributed to curbing electricity consumption through sophisticated controls, used for lighting, appliances, and climate control. Digital energy management control systems (EMCS) have already proven to cut energy use with a reasonable rate of payback for businesses as well as residences[52].

[48] Data was obtained from: http://www.eia.doe.gov/emeu/mer/txt/mer2-1 .
[49] Romm (1999), p.26.
[50] Ibid, p.34-36.
[51] Ibid, p.6.
[52] Ibid, p. 18 and 24.

The industrial sector generally comprises another major source of energy consumption. In the U.S., it is responsible for approximately 35% of all energy consumption[53]. In general, IT advances can help the industrial sector become more energy efficient by leading to reduced inventories, better utilization of space and other capacities, and more effective supply chains. In 2001, General Motors Corporation, Ford Motor Company, and DaimlerChrysler AG significantly improved their supply chains by moving their purchasing operations online and together forming one of the world's largest online marketplaces, called Covisint[54]. Covisint allows these automakers to quickly share critical information, such as inventory levels, usage history and patterns, forecast, receipts and other relevant information to help eliminate excess inventory. This IT solution allows the companies to monitor actual consumption, inventory levels, and respond quickly and efficiently to any changes, thereby leading to greater efficiencies in their manufacturing and energy consumption.

The transportation sector also typically has significant energy demands. In the U.S., it contributes to approximately 28% of all energy consumption[55]. The most significant positive impact IT can have on reducing energy use by the transportation sector is in the form of enabling more energy-efficient transportation substitution options, as is discussed in section 4.5. However, IT can also play a role in making transportation systems inherently more energy efficient through the use of Intelligent Traffic Systems (ITS). University of California's Center for Information Technology Research in the Interest of Society (CITRIS) estimates that these types of traffic optimization systems can help to save 15 minutes per commuter per day in California, reclaim an estimated $15 billion annually in lost wages, and reduce gasoline consumption by up to 150,000 gallons per day[56].

4.4 Economic Stimulation

Throughout the latter 1990s, positive economic impacts of IT could be seen most visibly in the United States. According to the U.S. Department of Commerce, although IT industries account for a relatively small share of the economy's total output (an estimated 8.3 percent in 2000), they contributed to nearly 33% of U.S. economic growth between 1995 and 1999[57]. Figure 4.3 illustrates the strong correlation between IT use and economic growth.

[53] Data was obtained from: http://www.eia.doe.gov/emeu/mer/txt/mer2-1 .
[54] http://www.covisint.com/ .
[55] Data was obtained from: http://www.eia.doe.gov/emeu/mer/txt/mer2-1 .
[56] See http://www.citris.berkeley.edu/applications/transportation/ .
[57] U.S. Department of Commerce (2000).

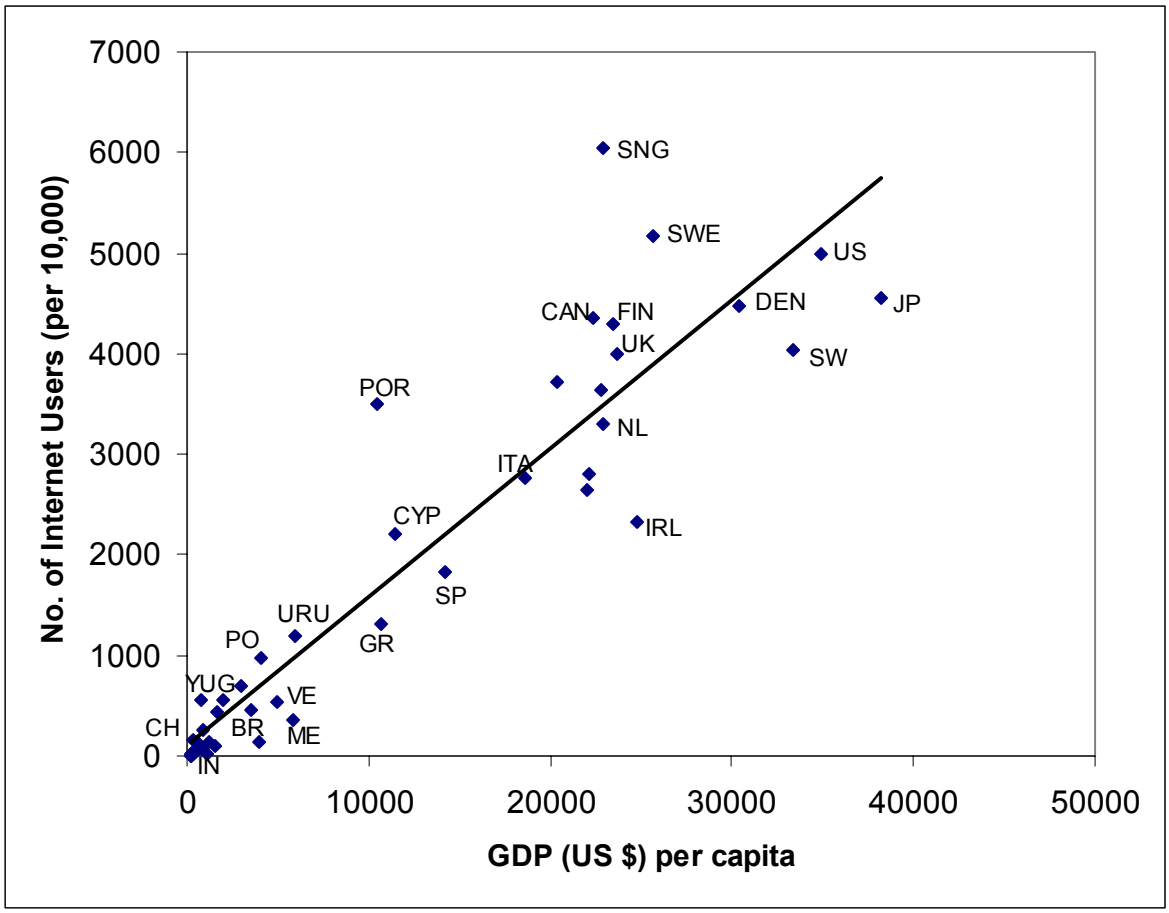


Figure 4.3 Relationship Between Internet Use and Economic Growth
Sources: World Bank (2000b) and International Telecommunications Union (2001)

The declining costs and growing availability and diffusion of IT leads to potentially great prospects for stimulation of developing economies. For example, IT enables developing countries to leapfrog old technologies, such as copper wires and analog telephones, and invest in a wireless infrastructure, which is typically cheaper to install and easier to maintain than the traditional land line infrastructure. Furthermore, IT helps to spur the growth of new and profitable sectors. For example, as illustrated in Figure 4.4, the software industry in India has shown tremendous growth.

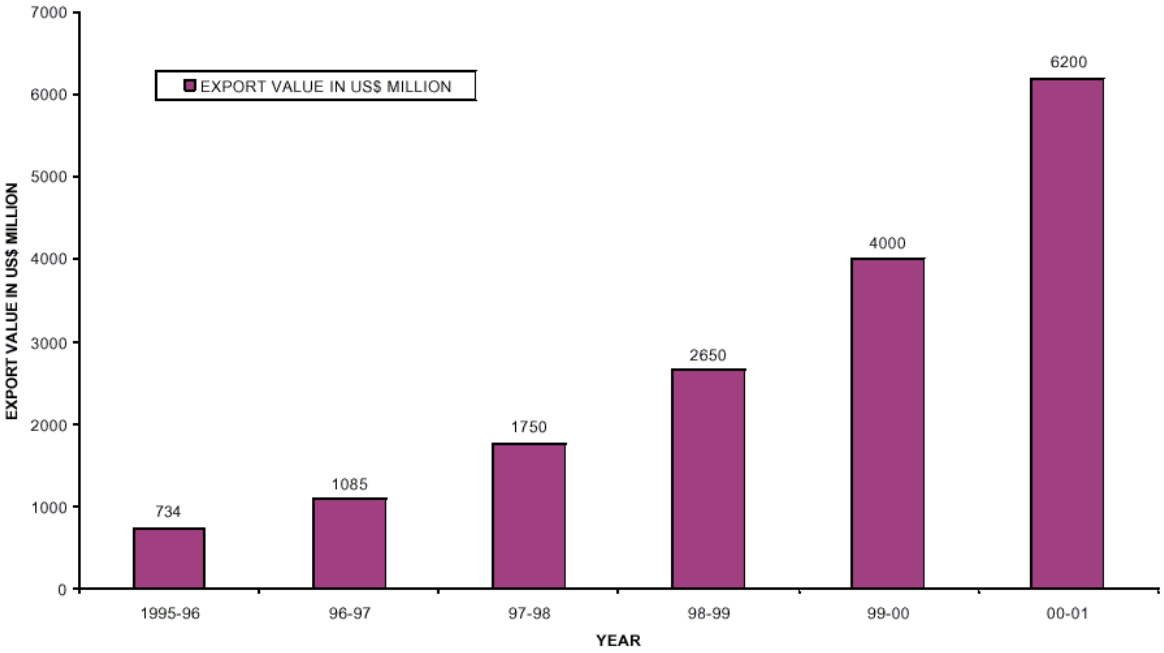


Figure 4.4 Software Exports in India, 1995-2001
Source: Nair et al. (2002)

India provides a good example as to how developing economies can be affected by IT investments. The Indian economy has benefited from an additional 92,000 new jobs and 250,000 indirect jobs due to the IT industry[58]. Furthermore, foreign direct investment due to IT is currently estimated at $800 million and is predicted to reach $1.2 billion by 2005[59].

4.5 Lifestyle Changes

IT has the potential to significantly affect sustainable development by affecting consumption patterns and preferences. One of the most prevalent current examples is teleworking, or telecommuting. IT advances have helped to provide transportation alternatives that are more amenable to sustainable development by reducing the transportation load due to commuting. Teleconferencing also allows employees to conduct meetings without having to travel. In addition, the availability of online stores has reduced the need to go to physical stores for shopping. Finally, transportation needs for the physical delivery of goods is being alleviated through the online delivery of goods, such as music, books, and other information that can be downloaded right to a user's computer without the need of a physical transportation intermediary. These examples help to illustrate how IT has led to the development of new services and have helped to shape consumer preferences as a result.

[58] National Association of Software and Service Companies (2002).
[59] Ibid.

4.6 Social Benefits

By enabling an unprecedented level of access to a vast world of knowledge, the IT revolution presents numerous opportunities to improve social conditions, particularly for the most disadvantaged segments of the world's population. For example, educational opportunities have grown significantly due to Internet-based, long-distance education and training. One of the most prominent examples of this is the African Virtual University (AVU), an Internet-based university that provides online education and resources to students in 17 African countries. Since its launch in 1997, AVU has taught semester-long courses in technology, engineering, business and the sciences to over 24,000 students[60]. AVU also provides its students with free email accounts and access to over 1,000 full text online journals. The Internet has enabled the university to develop collaborative partnerships with academic institutions all over the world. In the spring of 2002, over 190 students from eight sub-Saharan countries took an MIT course on Java programming. The students viewed videotaped lectures via satellite, accessed a web site for course materials, contacted teaching assistants via e-mail, and participated in live videoconferences with the MIT professor[61]. If implemented on a wider scale, distance learning has the potential to be one of IT's greatest contributions to sustainable development.

IT can also make significant contributions to social initiatives on a local level. Tarahaat.com, an Internet portal with a full range of services targeted to Indian rural villagers, contains links to vital information on health, water, sanitation, women's issues, education, community events, and agriculture. Aside from providing important information, Tarahaat.com also offers services to villagers. For example, Tarahaat users can ask medical questions from health professionals. Villagers can participate in e-commerce initiatives through the portal, selling their commodities to other villagers, and expanding their business to urban and overseas consumers as well.

TARAhaat.com was designed to accommodate a wide range of literacy levels, languages, and levels of understanding. As illustrated in Figure 4.5, the user interface relies on colorful graphics and icons to supplement, and sometimes substitute for, text-based navigation. The icons in the following figure are also voice-based, which are activated when the mouse rolls over any of the icons. This ensures that everyone can benefit from these services, regardless of literacy level. The text is currently available in Hindi and English, but other languages will be added as the portal expands its reach to other regions[62].

[60] African Virtual University (AVU) website: http://www.avu.org/ .
[61] http://web.mit.edu/newsoffice/tt/2002/apr24/avu.html .
[62] See http://www.tarahaat.com for more information.

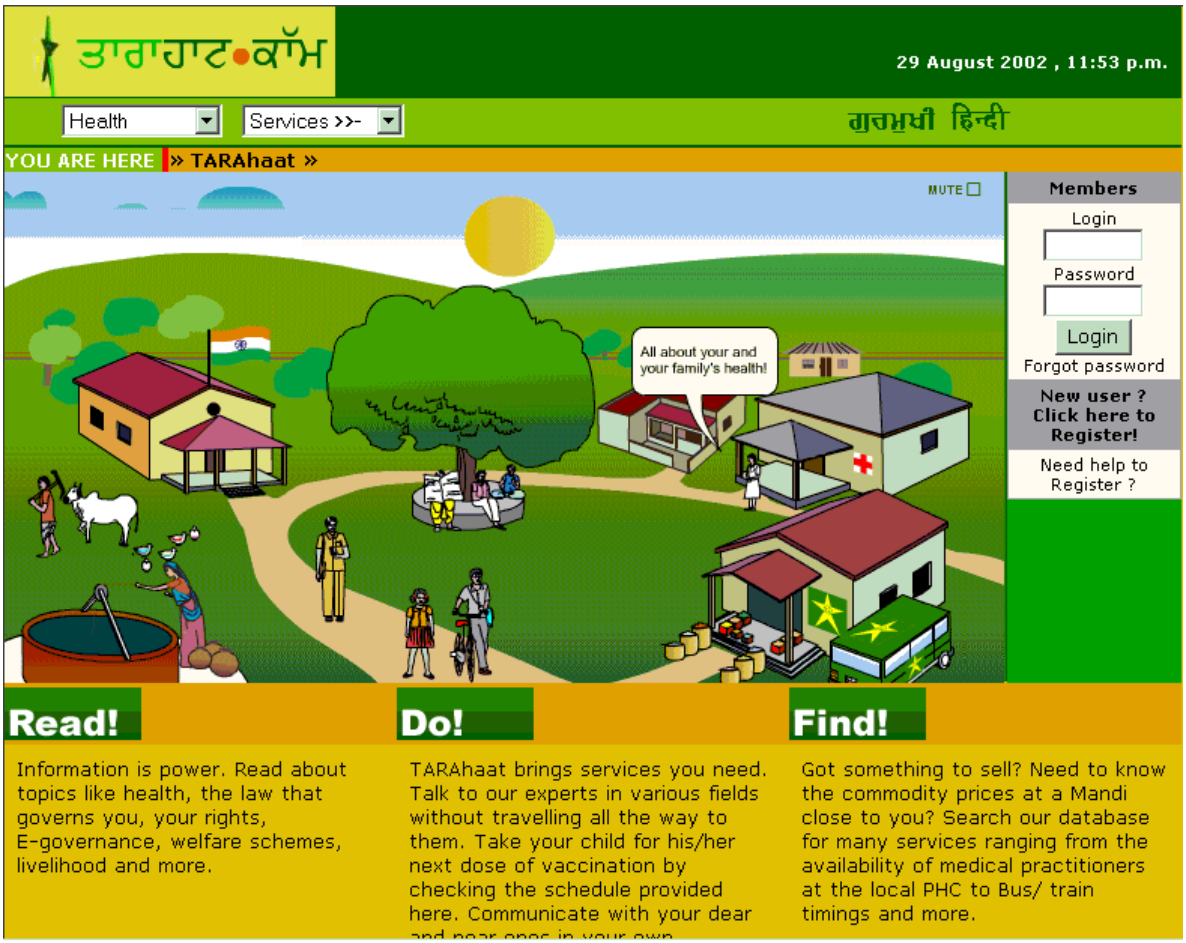


Figure 4.5 Tarahaat.com: A Portal Providing Social Services to Indian Rural Villages
Source: Tarahaat (http://www.tarahaat.com)

4.7 Information Integration

IT has made great advances in the ability to discover, retrieve, and integrate information from sources that are geographically dispersed, varying in context, and heterogeneous in format. Intelligent integration capabilities have had important applications in fields as diverse as environmental monitoring and financial services. Recent events have also demonstrated effective information integration to be an important form of counter-terrorism response. For example, more so now than ever, the U.S. Office of Counter-Terrorism and the newly-created Office of Homeland Security rely on intelligence information from all over the world to develop strategic responses to security threats. However, relevant information is stored in various regions throughout the world and by diverse agencies in different media, formats, and contexts. Intelligent integration of information is fundamental to developing policies to anticipate and strengthen protection against terrorist threats or attacks in the United States. The Laboratory for Information Globalization and Harmonization (LIGHT) at MIT is one example of a research

initiative that is examining how IT advances can be applied to address complex global challenges, such as terrorism and other security threats[63].

4.8 Knowledge Networks: GSSD Case Study

A powerful positive linkage is the ability for IT to serve as an effective knowledge tool because it enables:

- Rapid knowledge exchange;
- Broader access to experts;
- Facilitated experience sharing;
- Knowledge creation; and
- Knowledge dissemination.

These characteristics of IT have helped to shape what is known as the **knowledge network**. A knowledge network can generally be defined as knowledge transactions taking place among "a combination of persons, usually dispersed over a number of geographically separate sites, with appropriate communications technology[64]." Since the determinants of success in a knowledge-based economy largely depend on the effectiveness of gathering and utilizing knowledge, the knowledge network and its capabilities have gained prominence. As explained in Section 5, knowledge networks and similar IT-enabled functionality can serve as effective knowledge tools for developing countries.

Knowledge networks leverage the Internet's networking power with other IT tools, especially database-oriented technology, to provide access to knowledge tailored to specific needs. The Internet is a very useful platform for knowledge networks because of its ability to support many different applications, including email, file transfer, the World Wide Web, video, music, and conferencing. Software tools are used to organize these resources in a coherent manner.

Knowledge networks provide structure and meaning to this vast supply of uncontrolled information on the Internet. They have a well-defined theme with criteria for participation, so that only relevant knowledge is allowed to be part of the network. The Global System for Sustainable Development[65] (GSSD) is one example of an IT tool that relies on partners, or mirror sites, in the knowledge network to develop and organize localized content related to sustainable development. This content can then be transmitted through the system and distributed to other mirror sites. This knowledge network is basically a network of networks that allows for the effective development of localized knowledge, which can also be shared with the rest of the global knowledge network, leading to utilization, modification, creation, and dissemination of knowledge relevant to sustainable development. The GSSD knowledge network is described in detail in section 5.

[63] Choucri et al (2001).
[64] Clark, p.1.
[65] The GSSD web site can be found at: http://gssd.mit.edu.

5. IT and Sustainable Development in Context: Global System for Sustainable Development

5.1 Overview of the Global System for Sustainable Development (GSSD)

5.1.1 Conceptual Framework

The Global System for Sustainable Development (GSSD) is a Web-based global knowledge network devoted to organizing knowledge and guiding action related to sustainable development. The GSSD knowledge base consists of Internet-based resources from over 250 institutions worldwide, representing a diverse set of data by type, scale, and scope that is then cross-referenced and cross-indexed for ease of retrieval and analysis, according to an integrated and coherent conceptual framework covering the knowledge domain of sustainability.

The conceptual framework for GSSD helps to provide an operational definition of sustainable development and serves to provide linkages across multiple domains and levels of activity that are relevant to sustainability. The domain of sustainability is represented as a hierarchical and nested conceptual structure that spans 14 key socio-economic sectors of human activities. These sectors are depicted as “slices” in Figure 5.1.

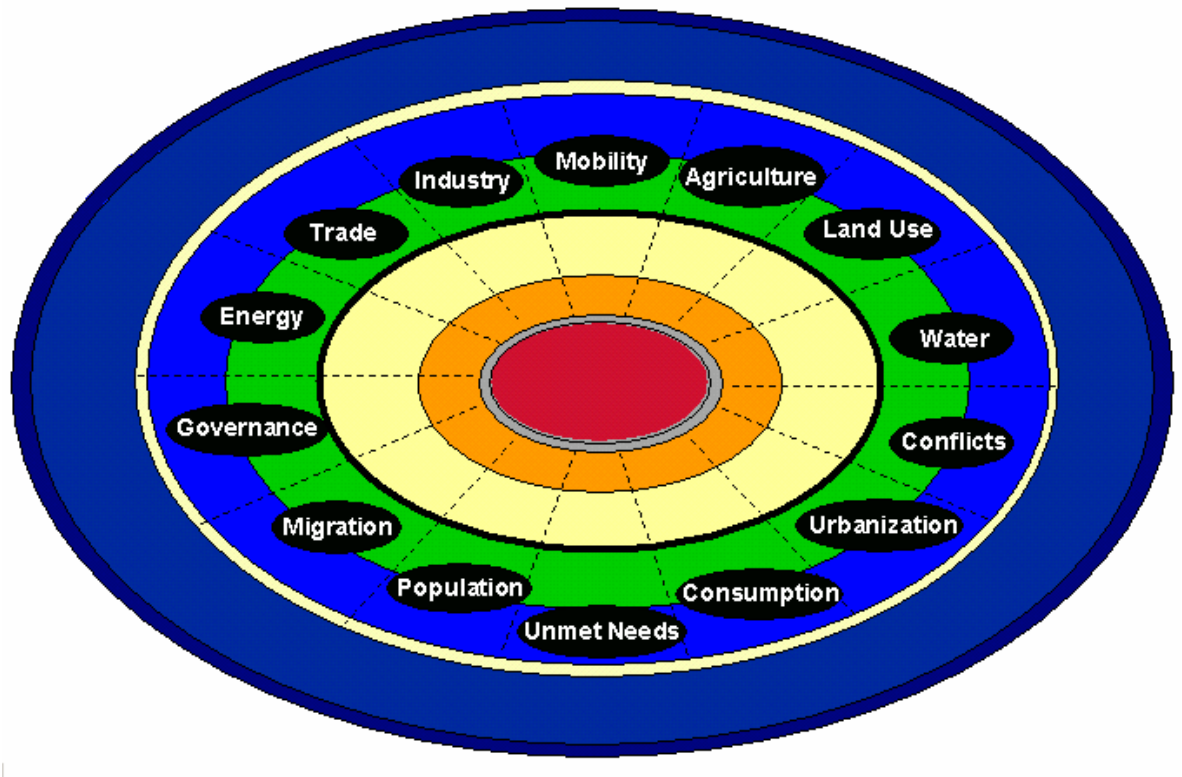


Figure 5.1. GSSD Conceptual Framework: Slices
Source: Choucri (2000)

These human activities that impact sustainable development can be examined from five different lenses: (1) the activities themselves, (2) the resulting sustainability problems, (3) scientific and technological responses to these problems, (4) political, social and regulatory instruments for addressing the issues, and (5) coordinated international actions in response to the problems. These various approaches are depicted as "rings" in Figure 5.2.

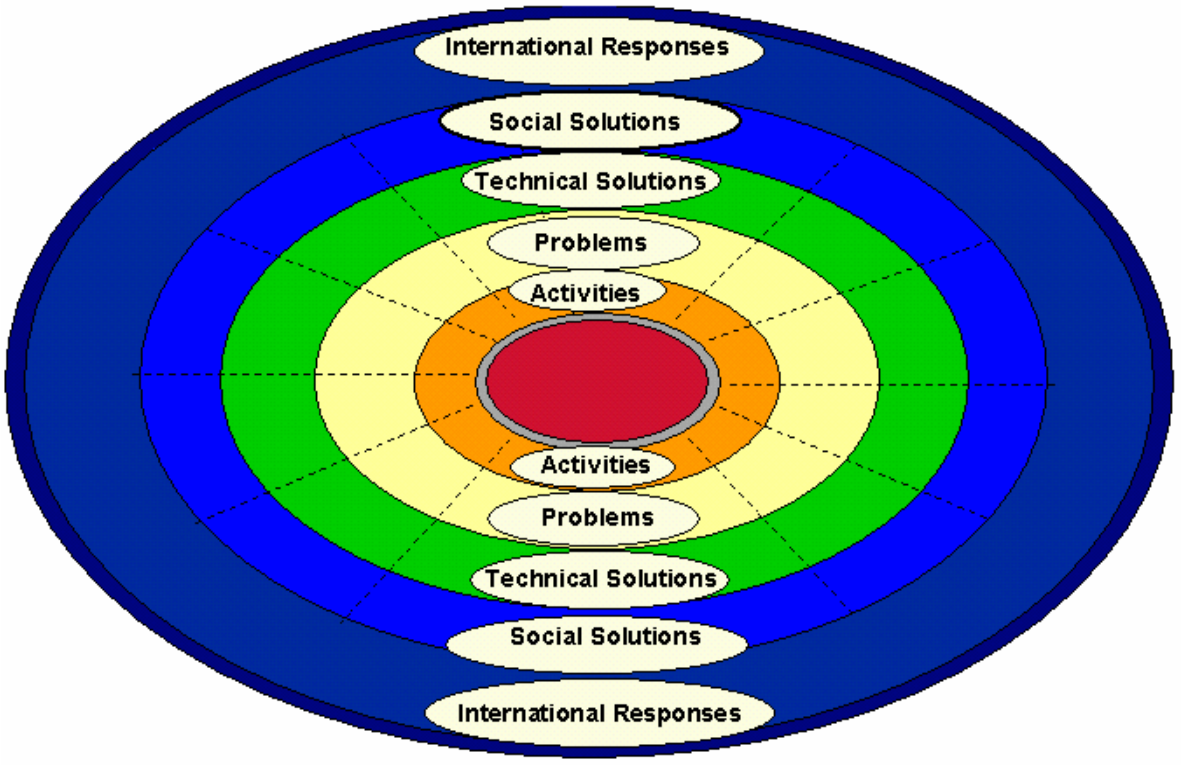


Figure 5.2. GSSD Conceptual Framework: Rings
Source: Choucri (2000)

By examining the intersections of these slices and rings, the GSSD conceptual framework enables an in-depth analysis of sustainable development at increasing levels of granularity. The intersection of a slice and ring produces a "cell" of knowledge relevant to sustainable development. That "cell" can then be unbundled into "concepts" for more detailed analysis. Finally "concepts" can be broken down into "sub-concepts," which provide information on sustainability issues at the finest level of granularity. Figure 5.3 illustrates the GSSD structure at increasing levels of granularity.

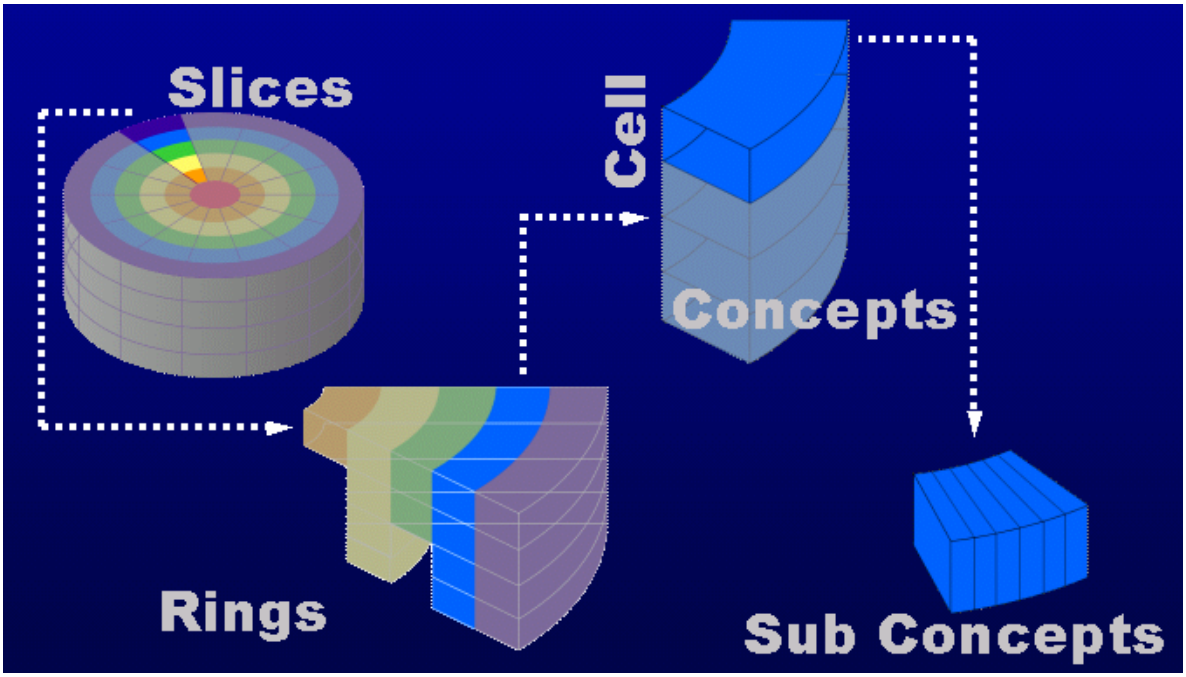


Figure 5.3. Levels of Granularity in the GSSD Structure
Source: Choucri (2000)

Figure 5.4 provides an example of how the GSSD conceptual design helps to organize and structure issues that fall into the broad realm of sustainability. This example deals with the broad area of agriculture. If one was specifically interested in sustainability problems, that is one level of specificity that already narrows the scope of the issue of interest. Next, within the broad area of sustainablity problems in agriculture, there are many relevant concepts, such as the threat of socio-economic dislocations as a result of unsustainable practices in agriculture. Within the concept of socio-economic dislocations, there are then sub-concepts related to this issue, such as economic impacts, which specifically focuses on how negative economic factors, such as unfair competition and market instability, can produce significant barriers to sustainable agriculture.

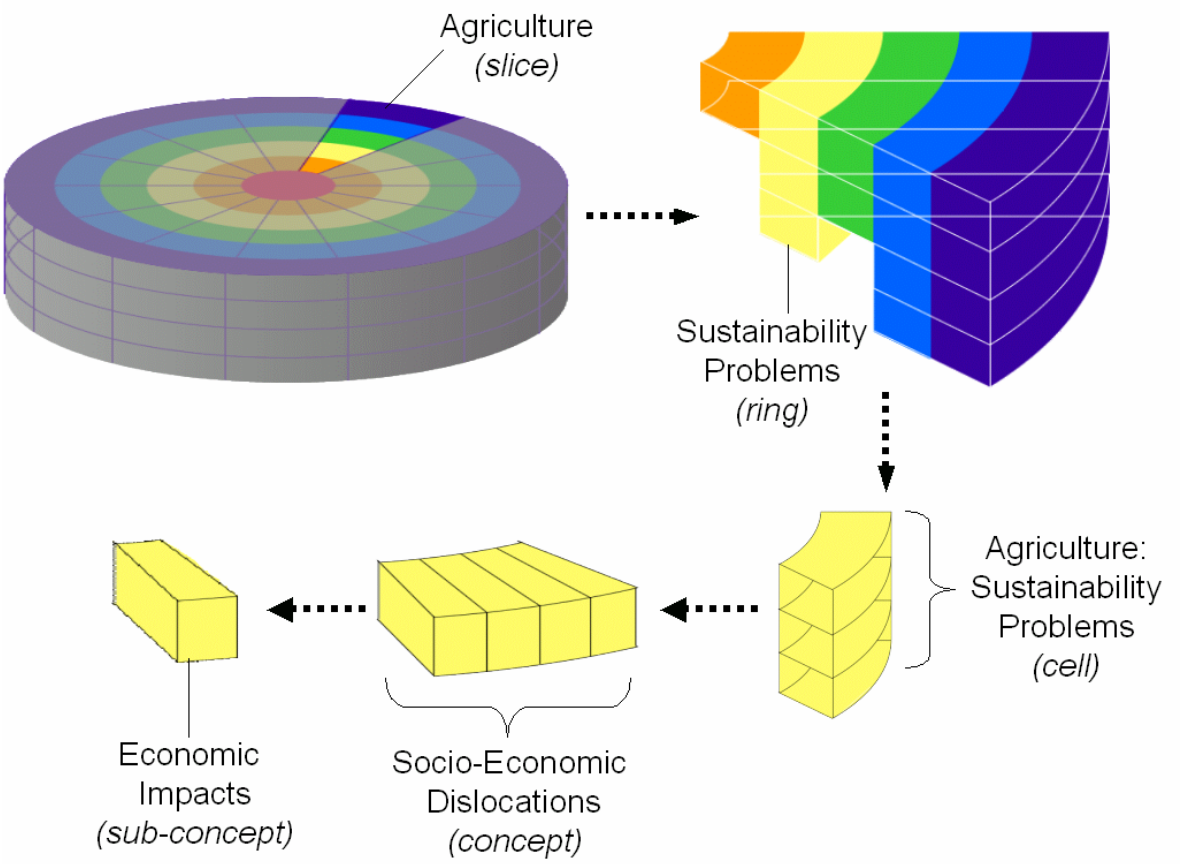


Figure 5.4. Levels of Granularity in GSSD: Agriculture Example
Adapted from Choucri (2000)

Although it is possible to go into further detail, the GSSD structure stops at this level of granularity. In other words, knowledge representation is not differentiated further. Currently, this design is sufficient to ensure adequate organization and representation of sustainability knowledge available on the Internet today. However, it is conceivable that, as Web-based knowledge and research into sustainability becomes more sophisticated, the conceptual design will need to be revisited to account for this increasing level of detail. Alternatively, if users seek more detailed specification of particular knowledge elements and their representation, greater granularity will be required as well.

5.1.2 Physical Structure

The GSSD knowledge base is supported by a physical infrastructure that is composed of four basic levels. The most basic component is the *server*, which relies on IBM Lotus Domino server software for operation. The server hosts a set of IBM Lotus Notes *databases*, which contain GSSD content in various languages. Each database is comprised of *documents*. There are two basic types of documents: static and dynamic. Static documents include content that rarely changes once it is incorporated into the system, such as reports. Dynamic documents include content that require periodic updating and/or maintenance, such as abstracts. Abstracts, which

are the main building blocks of the GSSD knowledge base, contain information on a sustainability-related resource on the Internet. These documents are created and maintained by *users*. As shown in Figure 5.5, the users are a fundamental component to the operational infrastructure of GSSD. Without the users to develop and maintain documents, GSSD would be a static and rather unremarkable system.

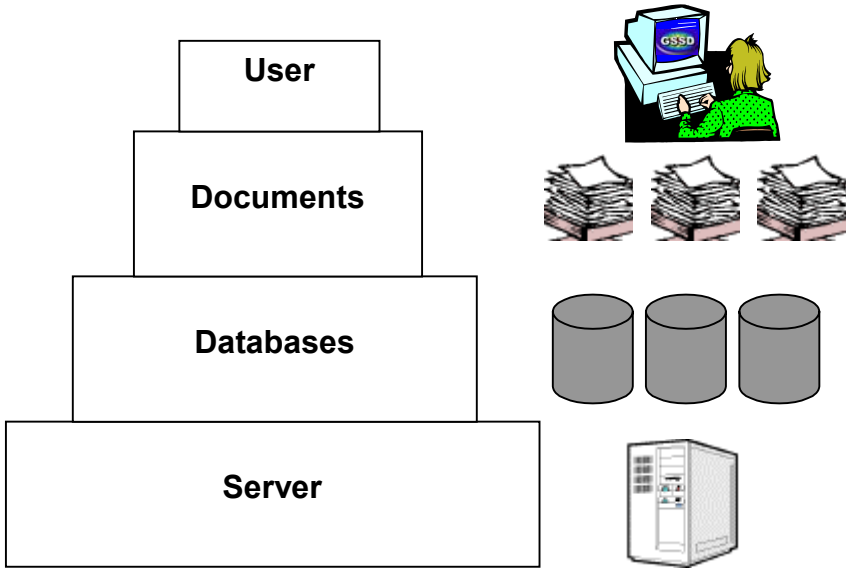


Figure 5.5. Physical Structure of GSSD

5.1.3 GSSD Partnerships and Knowledge Networking

GSSD partners are responsible for the oversight of the entire structure illustrated in Figure 5.5. As shown in Figure 5.6, GSSD partners play a critical role in ensuring the continued operation and growth of this infrastructure.

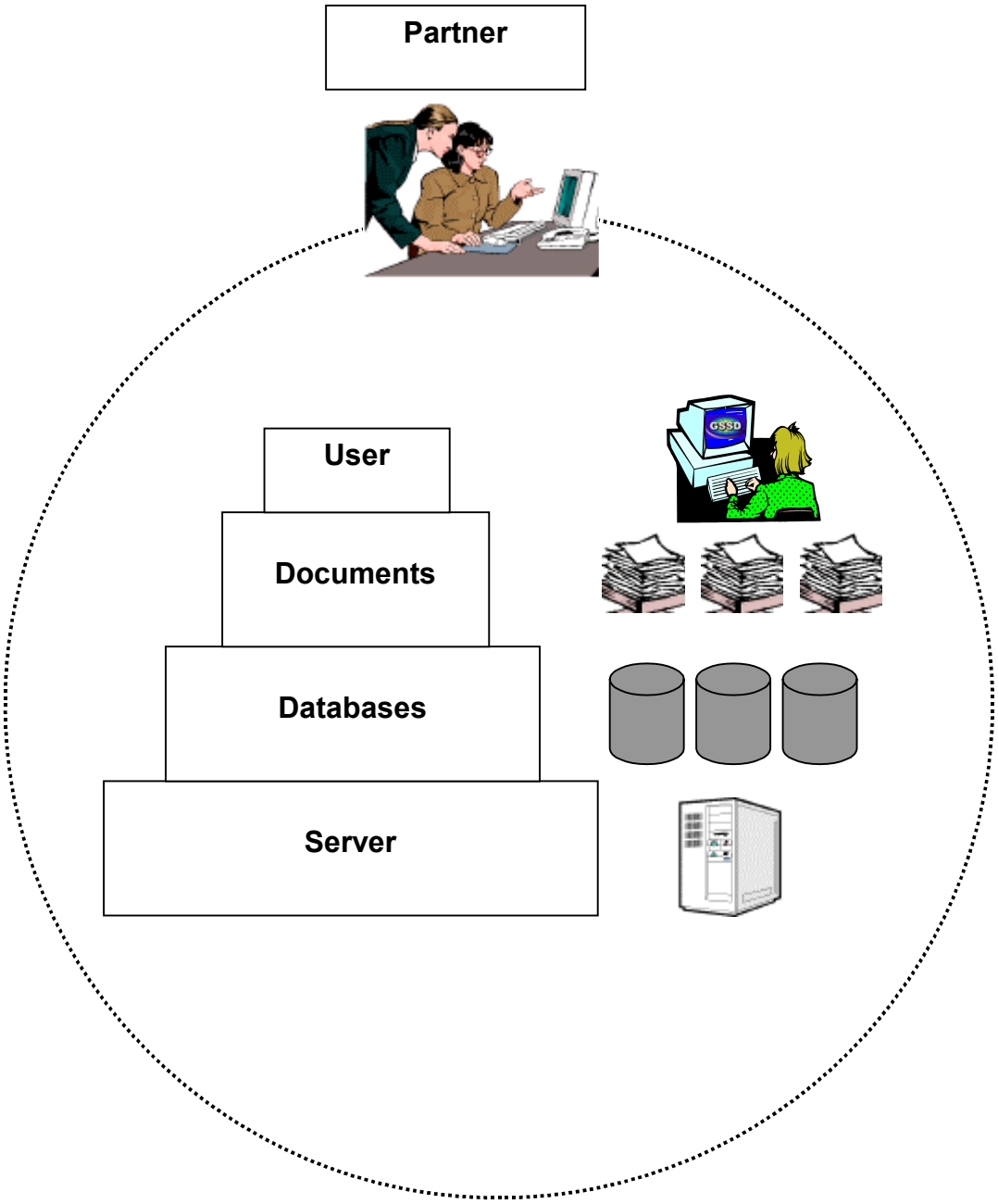


Figure 5.6. Critical Role of GSSD Partners

GSSD particularly relies on its partners, who are distributed all over the world, to develop and organize localized content related to sustainable development in their local languages. Partners are also crucial in providing translation of localized content, so that this knowledge can be accessible to a wider population of users.

The structure shown in Figure 5.6 is replicated across multiple locations, also known as mirror sites, to form the overall GSSD network, as shown in Figure 5.7.

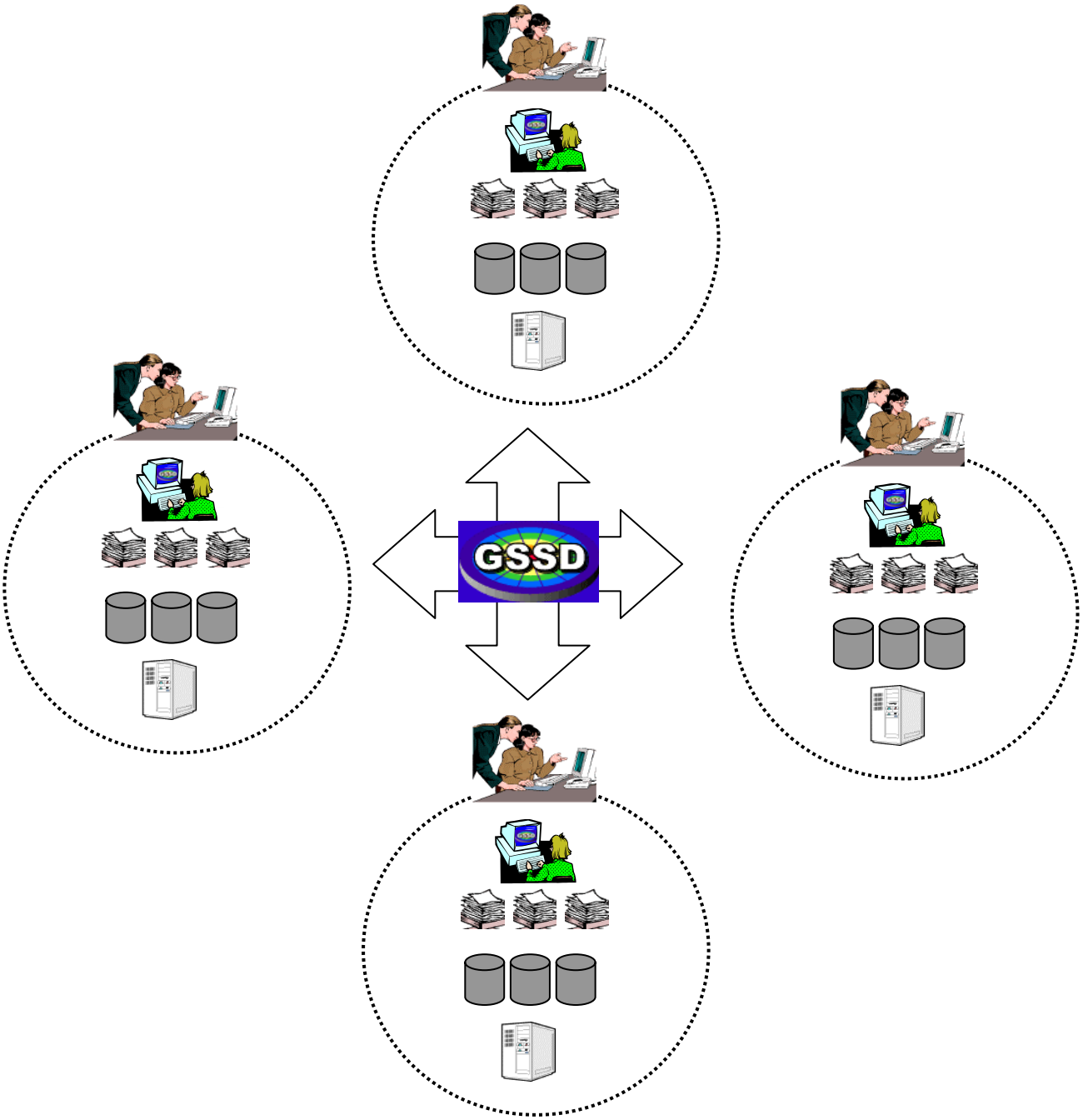


Figure 5.7. Overall Structure of the GSSD Knowledge Network

It is important to emphasize that the GSSD network is much more than just a physical network of servers distributed across the world. GSSD is also a knowledge network, as described in Section 4.8. Once GSSD partners develop localized content, it can then be transmitted through the system, translated into other languages, and distributed to other mirror sites. This knowledge

network is basically a *network of networks* that allows for the effective development of localized knowledge, which can also be shared with the rest of the global knowledge network, leading to utilization, modification, and creation of knowledge related to sustainable development.

5.2 Key Features and Contributions of GSSD: Addressing Six Major Barriers to Using IT for Sustainability

The core contributions of the GSSD system derive from its rich features, which were developed to address key barriers to leveraging IT for sustainable development. These obstacles, and how they are addressed through various elements of GSSD functionality, are described below.

5.2.1 Conceptual Framework to Address Theoretical Ambiguity

As explained in Section 3.2, one of the most significant barriers to implementing an IT tool for understanding and assessing sustainability issues stems from the conceptual ambiguity historically related to sustainability. In general, there has been a lack of theoretical frameworks developed for the systematic study of sustainability issues. This can be largely attributed to the differing definitions of sustainable development, as highlighted in Section 1.1.

As illustrated in section 5.1, GSSD is built from a conceptual framework that relies on an operational definition of sustainable development to unbundle the sustainability domains. By identifying key areas of sustainability (slices in the GSSD model) and key dimensions of these areas (rings in the GSSD model), the complex, multi-dimensional challenges of sustainable development are broken down into identifiable and tangible domains.

5.2.2 Robust Search Capabilities to Accommodate Diverse Information Needs

While the extent of sustainability challenges is global, the impacts of these issues are often local, thereby requiring local responses and strategies. As a result, Section 3.6.3.3 argues that, in order for IT tools to be effective at providing knowledge for sustainability, they must be able to accommodate diverse users with various information needs.

GSSD content, referred to as abstracts, is indexed and classified based on the conceptual framework described earlier. As a result, users can utilize the search engine in a targeted manner and selectively browse and retrieve abstracts from the knowledge base. Figure 5.8 illustrates the search capabilities of GSSD, and how different users with various information needs are able to extract relevant knowledge from GSSD.

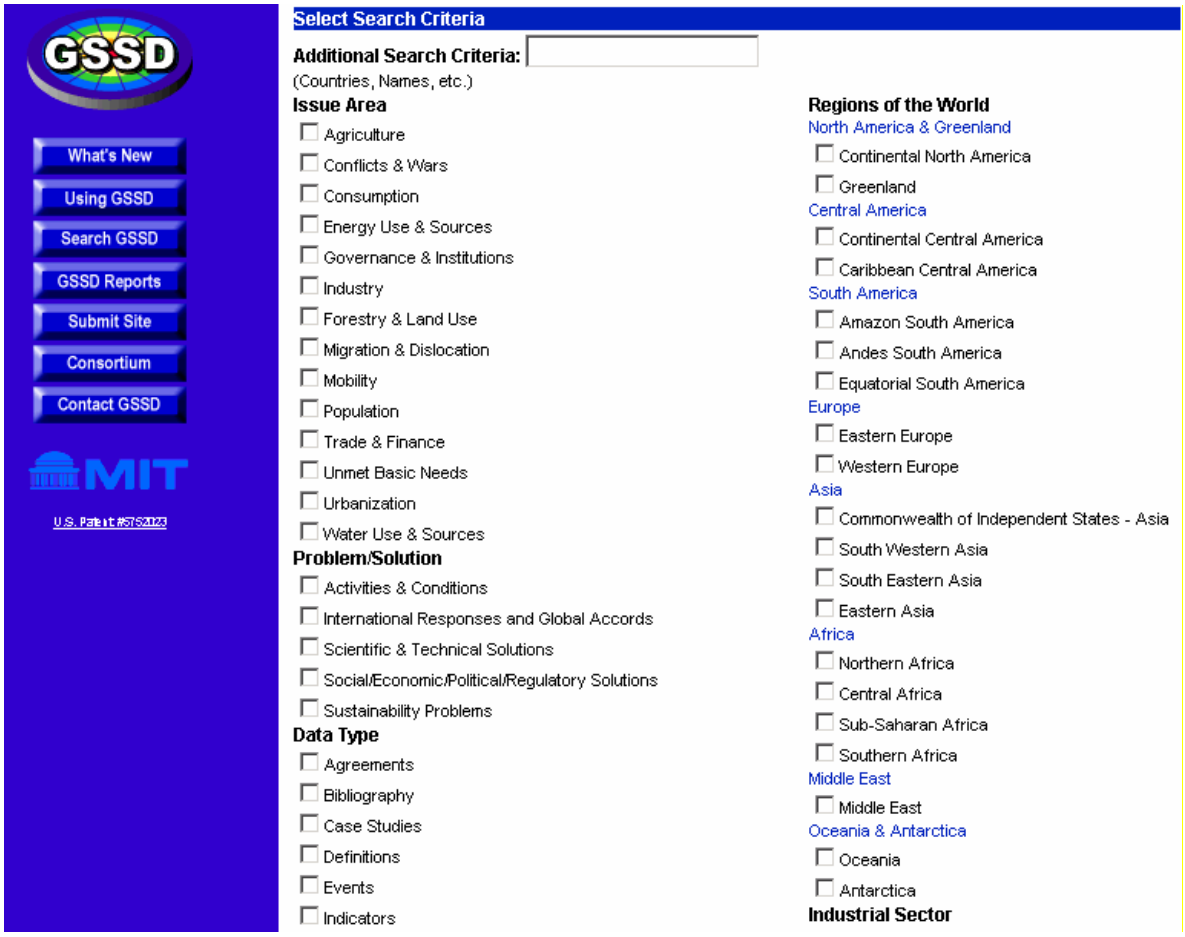


Figure 5.8. GSSD Search Capabilities

Source: GSSD web site (http://gssd.mit.edu/GSSD/gssden.nsf/searchFrameset?OpenFrameSet)

5.2.3 Support for Local Knowledge Provision

As discussed in Section 3.6.3.2, although the majority of sustainable development concerns and efforts are addressed on a local basis, this local knowledge is often not captured in a global knowledge network, resulting in significant barriers to building localized knowledge that can be used in sustainable development efforts.

GSSD enables and promotes local knowledge provision through its submission site, which allows users to input local knowledge to a centralized system and make it available to a global audience, thereby reinforcing and expanding the sustainability knowledge base. As discussed in the following sections, the multilingual and mirror site functionalities in GSSD bolster the support for local knowledge provision capabilities.

5.2.4 Multilingual Operations

While the English language dominates the content distributed over the Internet, sustainability issues are global in scope and affect a predominantly non-English speaking world. Therefore, as emphasized in section 3.6.3.1, any IT application that is directed towards sustainable development must provide multilingual capabilities to be effective at reaching a global audience.

One of GSSD's core strengths is its ability to support the development and provision of multilingual content. GSSD currently operates in Arabic, Chinese, and English, and is developing support for the French, Italian, Japanese, and Spanish languages. IBM Lotus technologies, which provide the technical infrastructure for GSSD, enable the easy translation of content and the expansion of the system into other languages. Figure 5.9 shows a screen shot of the IBM Lotus glossary tool used by the GSSD translation teams.

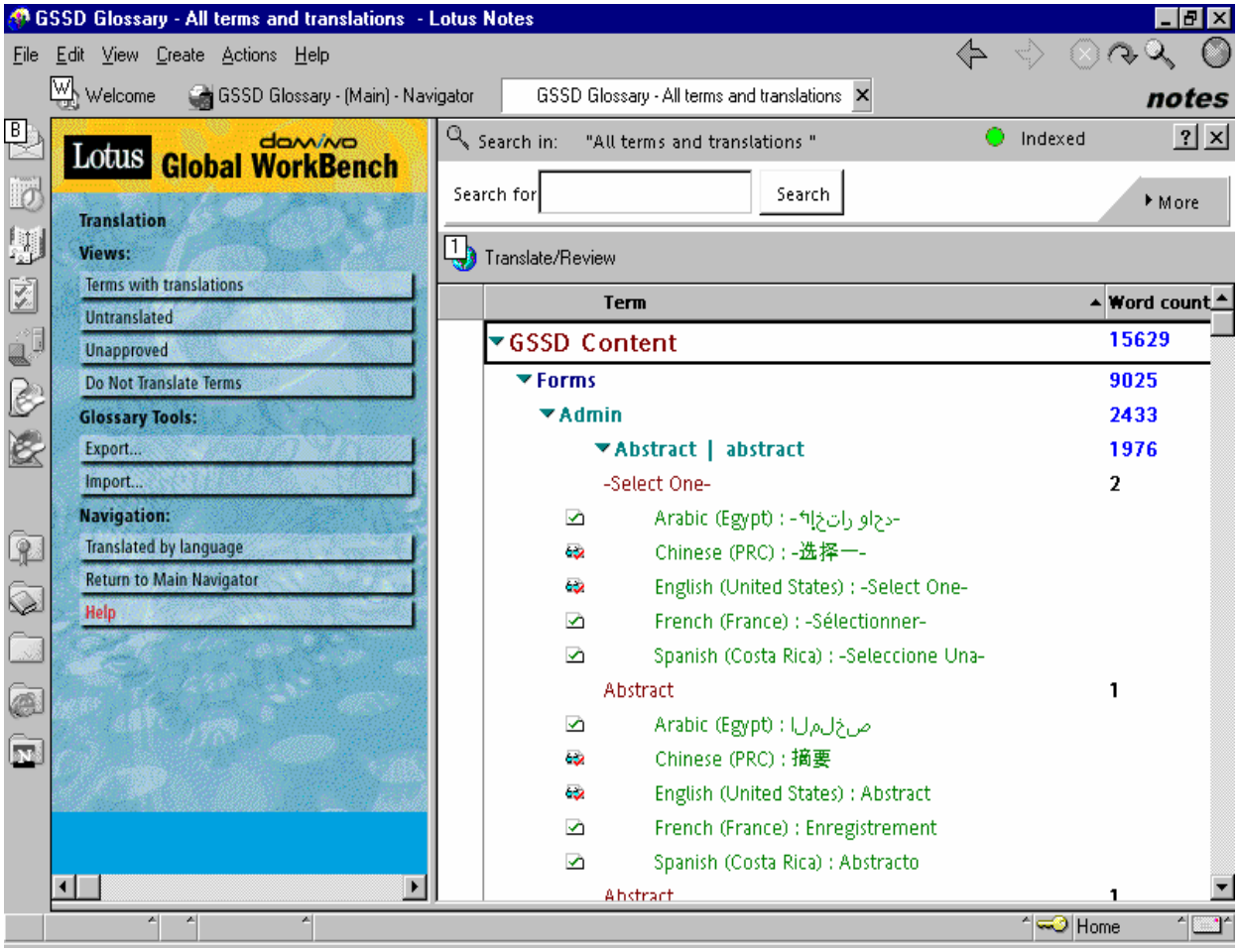


Figure 5.9. Screen Shot of the GSSD Glossary

In addition to the content, or abstracts, GSSD provides a multilingual technical interface, to allow its partners, who are involved with the technical development and management of the system, to develop code and design in their native language. This is a unique strength of GSSD

that allows it to draw valuable resources from all over the world to help with the improvement of the technical, as well as content, aspects of the system.

5.2.5 Transcending Physical Barriers

Although the "digital divide" debate has partly shifted focus to the importance of non-physical factors related to Internet access, access to IT infrastructure remains an important, and very real, issue for many developing countries. Therefore, for IT applications to have significant value for assessing sustainability issues in the developing world, the physical barriers related to infrastructure and access must be addressed, as discussed in Section 3.6.2.

GSSD helps to improve infrastructure quality and bandwidth capacities by deploying "mirror sites" across the world. These mirror sites result from fruitful partnerships with institutions that provide reliable IT infrastructures as well as the capacity for local and multilingual knowledge provision. The GSSD mirror site network is strengthened by the diversity of its members, which includes cross-national (China, Japan, and countries in the Middle East and Europe) and institutional partners (private, public, and international agencies). By collaborating with these institutions, the physical infrastructure for hosting GSSD content is reliable and stable, independent of geographic location.

Furthermore, by providing "mirror site" access, GSSD users can enjoy greater flexibility and convenience in accessing GSSD material. For example, in China, it is well-known that access to bandwidth is greater within the country than connecting to a location outside of the country. As a result, the GSSD mirror site in China will be much easier to access for Chinese users who would be likely subjected to delays and interruptions if they tried to access the GSSD mirror site in the U.S. Similarly, an Arabic-speaking user in France would likely have an easier time navigating the GSSD site by accessing the Arabic version of GSSD on the local French server, rather than on the Chinese mirror site.

As discussed before, an important physical constraint is bandwidth capacity, which is often limited in many developing areas of the world. Abstracts provide a means for GSSD to help overcome this limitation. Instead of providing an immediate link to an Internet-based source of sustainability information, GSSD provides a short summary, or abstract, which describes the content provided by the source, thereby resulting in less need for bandwidth and enabling a GSSD user to determine whether or not the site is useful before actually having to connect to the higher bandwidth-consuming site.

5.2.6 Quality Control to Prevent "Information Overload"

There is no doubt that the quantity of information available over the Internet is immense and still growing. While this trend is, in many ways, favorable for accessing information related to sustainable development, Section 3.3 points to serious implications for the quality of information accessed over the Internet. Search engines, such as Yahoo!, typically return a large number of search results for any query. Typical problems with the search results are that they: contain

irrelevant content, come from unreliable sources (e.g., personal home pages), and contain outdated or invalid links.

The GSSD knowledge base only contains pre-selected and quality-controlled information relevant to sustainability issues. All content that is submitted to GSSD is subjected to a detailed and rigorous approval and workflow process, and must adhere to a set of quality standards before it can be published for use. As a result, the information provided by GSSD is: streamlined to only include content relevant to sustainable development, generated by institutions that adhere to a strict set of data quality standards, and maintained to ensure that all content contain active and updated links.

5.3 GSSD Administration: Organizational, Institutional, and Technological Barriers

The GSSD system has been in operation, in one form or another, for approximately four years. Over the years, a series of organizational, institutional, and technological challenges have emerged, raising serious challenges to the effective administration of the system.

5.3.1 Organizational Issues and Institutional Imperatives

Over the course of GSSD's history, significant organizational barriers have developed within and across the partner institutions that together comprise the GSSD system. The following examples illustrate some of the issues that have posed significant challenges to the efficient administration of GSSD.

GSSD has suffered from high turnover rates, particularly in the MIT staff. This has resulted in inefficient management, due to the resulting levels of inexperience and the constant need for training of new staff. This is largely due to the fact that the MIT staff mainly consists of students, who have a relatively limited residence time at school and are unable to commit significant time investments to the project.

IBM Lotus Corporation, GSSD's current technology collaborative partner, has struggled to provide adequate and consistent technical assistance to meet the complex needs of the GSSD system. As an example, the IBM Lotus technical liaison to the project has changed six times over the last two years. As shown by the timeline in Figure 5.10, this turnover has contributed to substantial delays in addressing technical issues, as well as an inconsistent and inefficient approach to the technical operation of GSSD. This inefficiency was compounded by the change in organizational culture at Lotus, which was struggling with the transition from being an independent, innovative, and flexible company to being part of a more bureaucratic and rigid structure as a result of the IBM takeover.

The diversity and institutional nature of our partners also presented considerable challenges for GSSD administration. Cross-institutional management in itself is usually a challenging task, because each institution has its own policies and goals, which do not often overlap, and often conflict, with other institutions' imperatives. In addition to being distributed across institutions,

GSSD partners were also distributed across countries. The institutional partners at the time of this thesis included: American University of Beirut in Lebanon, the Ministry of Science and Technology in China, University of Tokyo in Japan, and Ecole Nationale Supérieure des Mines de Saint-Etienne in France. Therefore, differing cultural norms presented an additional layer of complexity to GSSD management. This diverse set of partnerships reflects the reality of managing a global system and the challenges related to IT applications for this context.

The institutional imperatives of GSSD partners translated into a series of technical requirements for GSSD. For example, it is important for partners to maintain control and ownership, and assert a certain level of independence from the main GSSD administrators and developers in the U.S. It is therefore critical for GSSD to have a decentralized structure. As a result, the design has been configured as a "hub and spoke" system, where the "hub" represents the main administrative and development activities which take place on the server in the U.S. (called the Stage server), and the "spokes" represent the mirror sites, which are essentially independent from each other, yet still maintain a direct line to the hub for necessary updates and upgrades.

Furthermore, the institutional partners supported technical efforts as long as it resulted in less work, and therefore less costs, for them. This is understandable given that these institutions often face limited budgets and restricted resources. As a result, in January 2001, during the annual GSSD meeting, there was a strong push from the partners to refine the design, which was originally structured in a manner that required a tedious and manual process for translation, which constitutes a significant bulk of the partners' work. Section 5.3.2 highlights the technical issues that have resulted from organizational and institutional demands.

These requirements resulted in a significantly more complicated technical design of the system, and was consequently resisted by IBM Lotus, who believed that the system essentially worked fine "as is." In fact, they did not understand the complexity of applications of their own product in a new domain. As shown by the timeline in Figure 5.10, these differences in approach and priorities have led to a protracted process which is still in progress.

Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01
Author joins GSSD as Administrator.	Serious technical issues are identified.	The first IBM Lotus liasion is consulted, who then defers to a 2nd IBM Lotus consultant, who has previous experience with GSSD.	Discussions continue with the 2nd IBM Lotus contact. An annual meeting of GSSD partners raises a new set of requirements.	GSSD and IBM Lotus reach an agreement to re-design the system based on the technical issues and partner requirements. A milestone of 3/31/01 is set for implementation.	New workflow diagrams are developed and the 3rd IBM Lotus developer prepares the new design to accommodate the new workflow.	The 3rd IBM Lotus developer comes to MIT to implement the new design. New issues arise and the IBM Lotus provides a new milestone for completion of 5/31/01. A meeting for 6/20/01 is also set to discuss the progress and user feedback for the new design.	IBM Lotus development continues. Discussions between MIT and IBM Lotus regarding the new design continue.		The 3rd IBM Lotus developer returns to MIT to implement the new design. The new design is not fully completed during their stay, leading to more follow-up work by MIT with remotely provided instructions by IBM Lotus. After testing, GSSD determines that there are still unresolved technical issues.	As a result of the design changes, there are now issues with the live GSSD site. A 4th IBM Lotus developer is brought in to address these new issues. The solution requires a significant amount of manual work by the GSSD team. A list of less critical technical issues are still unresolved.

Figure 5.10a Recent Timeline for the GSSD Project

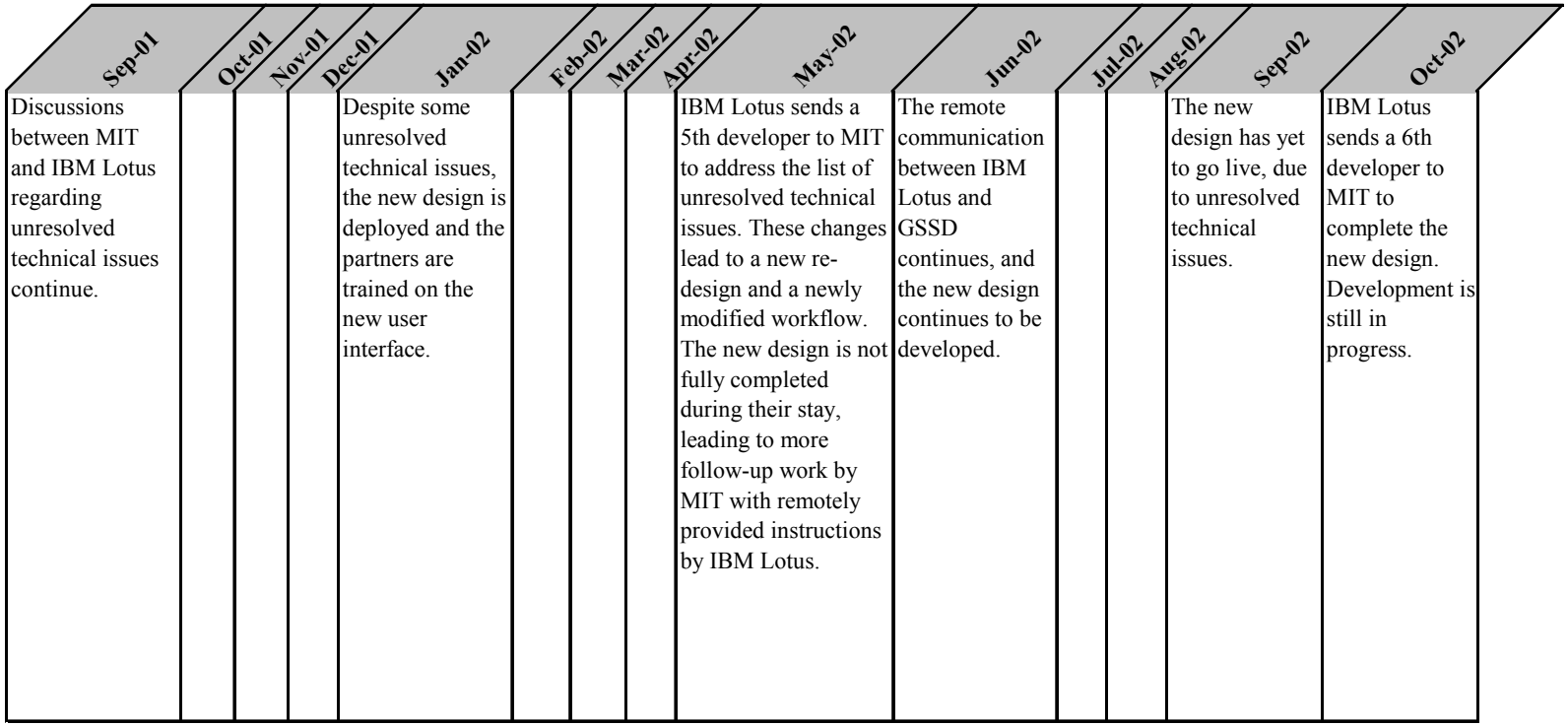


Figure 5.10b Recent Timeline for the GSSD Project

5.3.1.1 IBM Lotus Technology and Organizational Change

There is a significant body of literature devoted to technological impacts on organizational structure and processes, especially focused on IT's role in redefining organizations. IBM Lotus tools, the IT application used to develop and operate GSSD, have been the focus of a few of these studies[66]. Based on the empirical findings of this research, collaborative computing technology (also known as groupware) such as IBM Lotus Notes is unable to enact organizational change on its own. A number of organizational characteristics, such as cultural (how people understand and appreciate technology) and institutional (incentive systems and other norms) properties, significantly influence how IT is implemented and used by organizations.

The GSSD case study appears to confirm these findings. As discussed in Section 5.3.1, organizational and institutional constraints greatly impaired the ability to utilize the IBM Lotus technology to its greatest potential. However, these issues enabled a valuable transformation of the GSSD system, whereby the IBM Lotus application was transformed into an even better tool as a result, as shown by its new global workflow capabilities, which are described further in Section 5.4. Furthermore, the overall adoption of the GSSD groupware technology is due to the consensus, shared by all GSSD partners, that cooperation and collaboration are key elements of the project's success. As a result, the cooperative cultural structure of the GSSD "organization" was receptive to the IBM Lotus architecture and helped to ensure full leveraging of the tool's capabilities as a result.

5.3.2 Technological Issues

The organizational issues and institutional imperatives of GSSD partners described in the previous section have translated into a series of technical requirements for GSSD. To ensure that the system operates in its intended manner, the following main technical requirements were formulated by the GSSD team and directed to the IBM Lotus developers to incorporate into the system's design:

- When an abstract is submitted at one mirror site, it is eventually transmitted to all other mirror sites.
- When an abstract is submitted in one language, it is eventually translated into all other GSSD-supported languages.
- Abstracts are translated once the English version of the abstract is completed.
- Abstracts are published once the English version of the abstract is published.
- Simultaneous changes to an abstract are not allowed (typically referred to as "locks" in database terms).

[66] For example, see Orlikowski (1992) and Orlikowski (1995).

- When a change is made to an abstract, that change is propagated to all language versions of the abstract.
- When a change is made to an abstract, that change is propagated to all other mirror sites.
- The user interface needs to be easy to use, to ensure that the complexity of the backend operations is transparent to the users.
- The design should take up the least amount of disk space and require minimum bandwidth, to encourage maximum utilization of the system by partners as well as web users.

The bulk of the technical issues affecting GSSD stem from the system's inability to address the above requirements adequately. As shown by the timeline in Figure 5.10, many of these issues are still in the process of being addressed. As mentioned earlier, much of this inefficiency was caused by the reluctance of IBM Lotus to adapt its technology to meet GSSD's contextual conditions. As a result, GSSD has often been forced to compromise its project goals and priorities by adapting to the limitations of the IBM Lotus technology.

5.4 Responses to Critical Technological, Organizational, and Institutional Challenges: An Innovative Global Workflow Application

5.4.1 Evolution from Knowledge Network to Global Workflow Application

The technological, organizational, and institutional issues that have arisen over the last several years have resulted in a substantial redesign of the GSSD system. As a result, a significant contribution of this thesis is the development of an innovative global workflow application. Initially, GSSD was designed as a knowledge networking application, intended to foster the distribution and provision of sustainability-relevant knowledge, in local contexts, multilingual formats, and distributed geographic locations all over the world. However, the organizational and institutional priorities, and the subsequent technical requirements, helped to formulate a new experiment which transformed GSSD into a unique technical application for managing global workflow processes.

The experiment described in this section develops the notion of a **global workflow**, which is defined as the management of content that flows between users, databases, and servers that are distributed across languages and geographical spaces. In the context of GSSD, content that enters the GSSD global workflow originates from a single language and location. By the end of the workflow process, this content is converted into all supported languages and resides on all mirror sites of the GSSD network. The importance of this process to the GSSD system is illustrated in Figure 5.11.

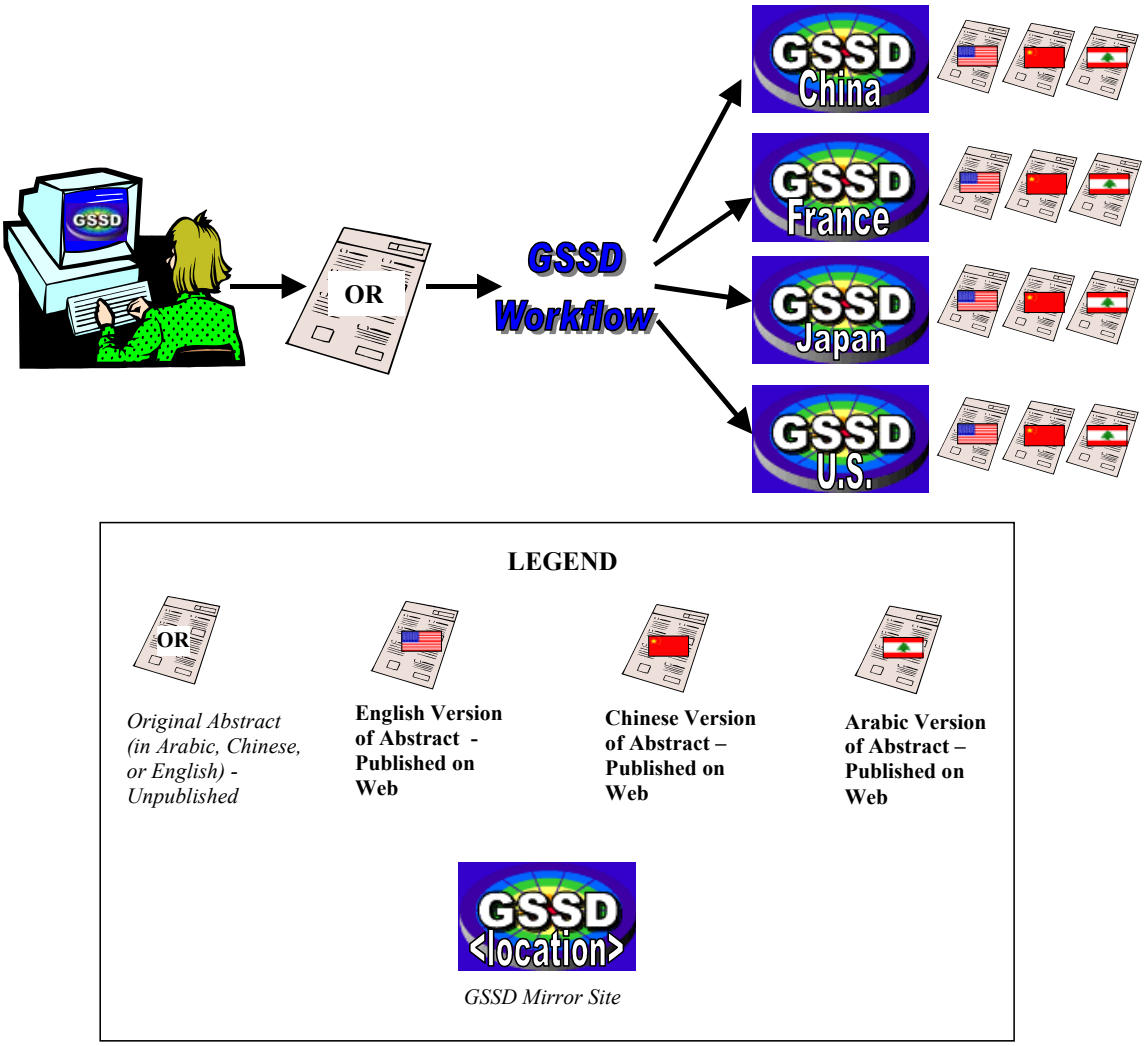


Figure 5.11 Importance of Workflow to the GSSD System

5.4.2 Development of a Global Workflow Application

The purpose of this section is to open the "black box" labeled as "GSSD Workflow" on Figure 5.11 and explain the mechanisms of the process. As described earlier, this new workflow was designed in response to a series of technological, organizational, and institutional challenges that arose during the development of GSSD.

There are three possible workflow scenarios for submitting an abstract to GSSD:

- *Local submission* – an abstract is submitted to a mirror site in the local language of that mirror site (e.g., a French abstract is submitted to the GSSD France server);
- *Non-local submission* – an abstract is submitted to a mirror site in a non-local language of that mirror site (e.g., a French abstract is submitted to the GSSD China server);

- *Multi-local submission* - an abstract is submitted to a mirror site which supports multiple languages (e.g., an Arabic abstract is submitted to the GSSD staging server, which supports both Arabic and English translation);

The above differentiation was developed during the design of the new global workflow process, and helped to define the various combinations of pathways that were possible for an abstract submitted to the GSSD global system.

Figure 5.12 below provides an example of a local submission workflow. This diagram also provides insight into the method that was developed to design the new workflow. The visual approach shown in Figure 5.12 provided an effective way to trace the scenario from the beginning, when a document is submitted to GSSD for review, to the end, when it is published in all supported languages and available on all mirror sites. On the figure, each supported language is displayed as a different shape and each available mirror site is shown as a labeled rectangular box around the supported language databases (see the legend at the end of Figure 5.12 for more details).

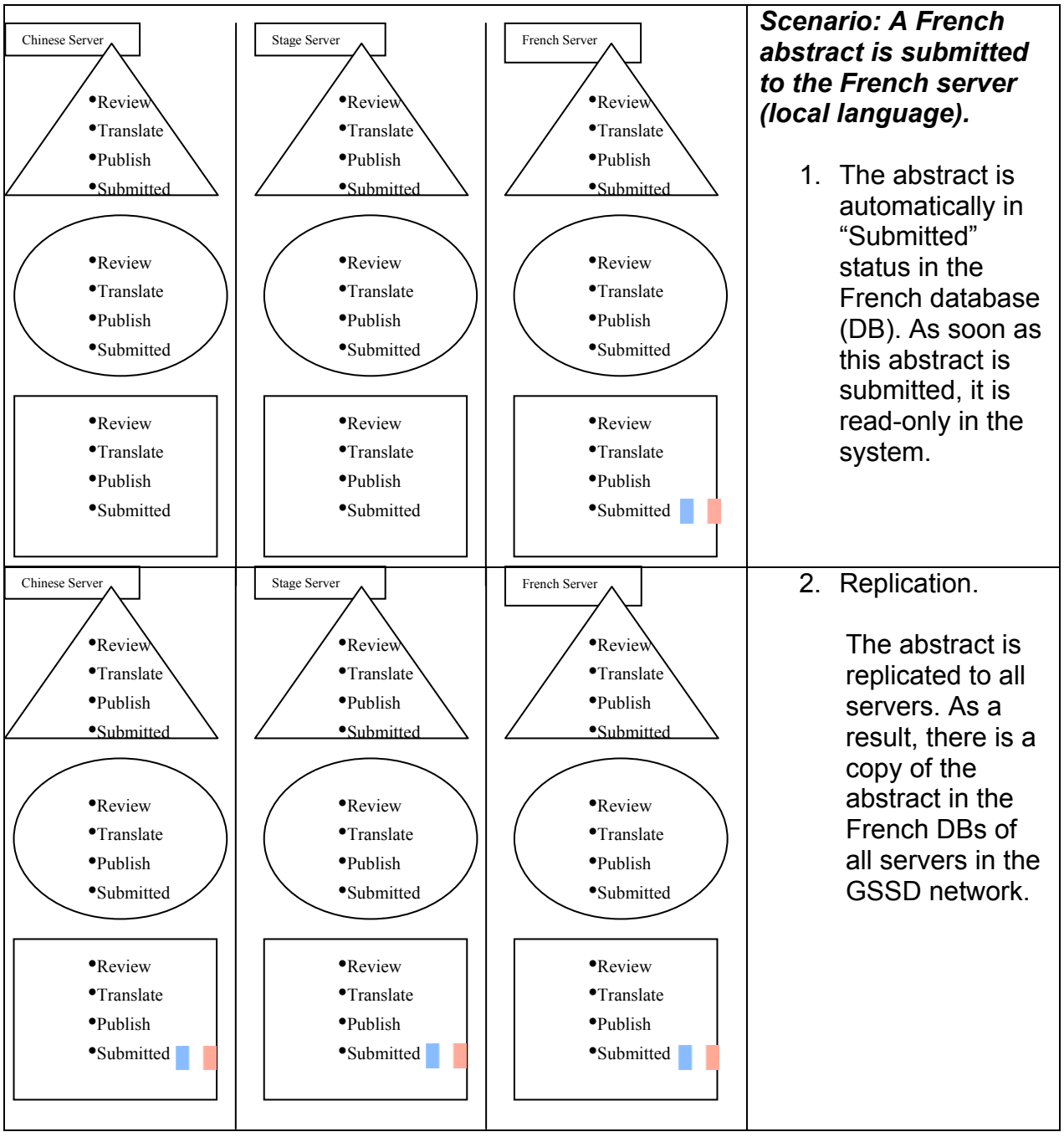
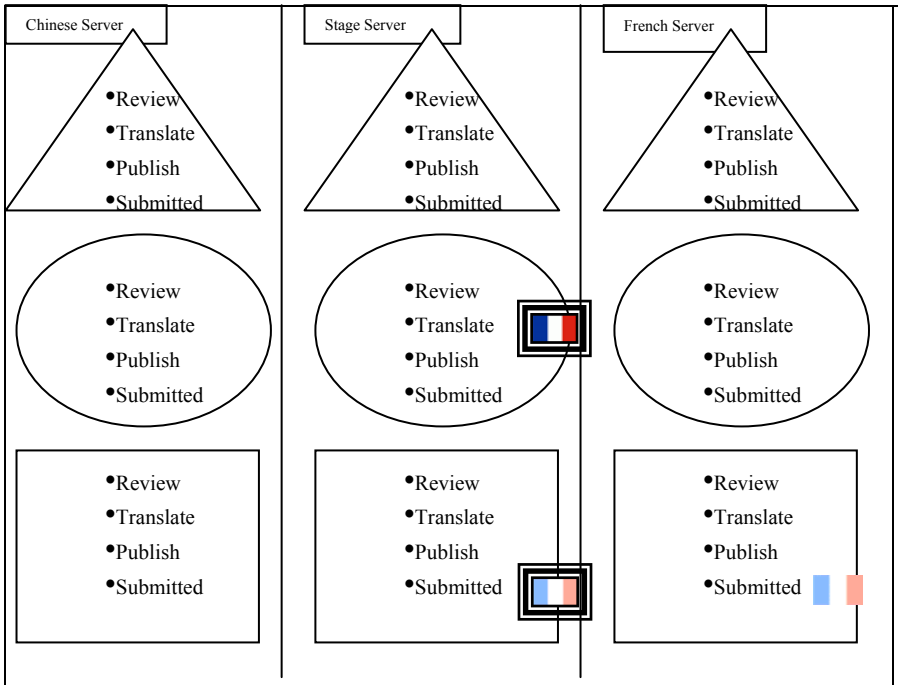
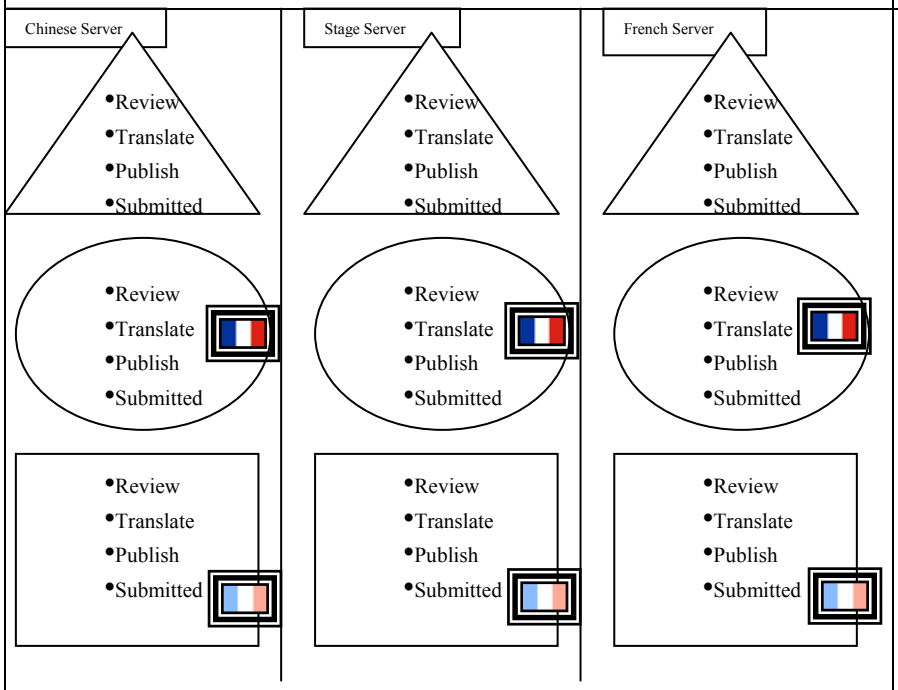


Figure 5.12a GSSD Global Workflow Process



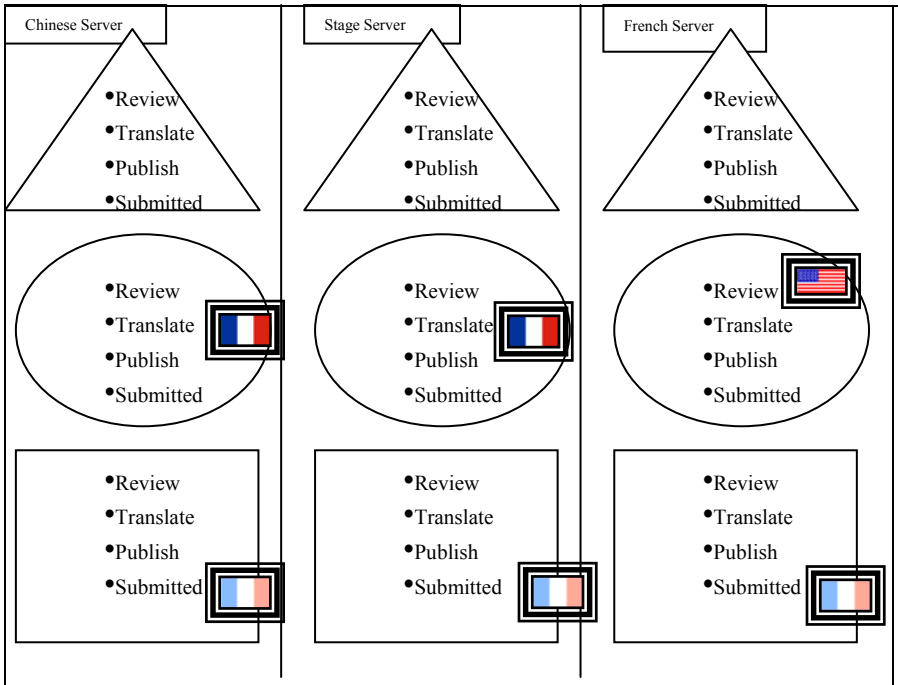
3. Synchronization takes place on the Stage server. This results in the following:

- The abstract is copied to the English DB (nothing in the Chinese DB) in a "Ready for Translation" status.
- The abstract in the French and English DBs are synchronized with each other. This means that the system recognizes them as the same abstract, even though they will later be in different languages.

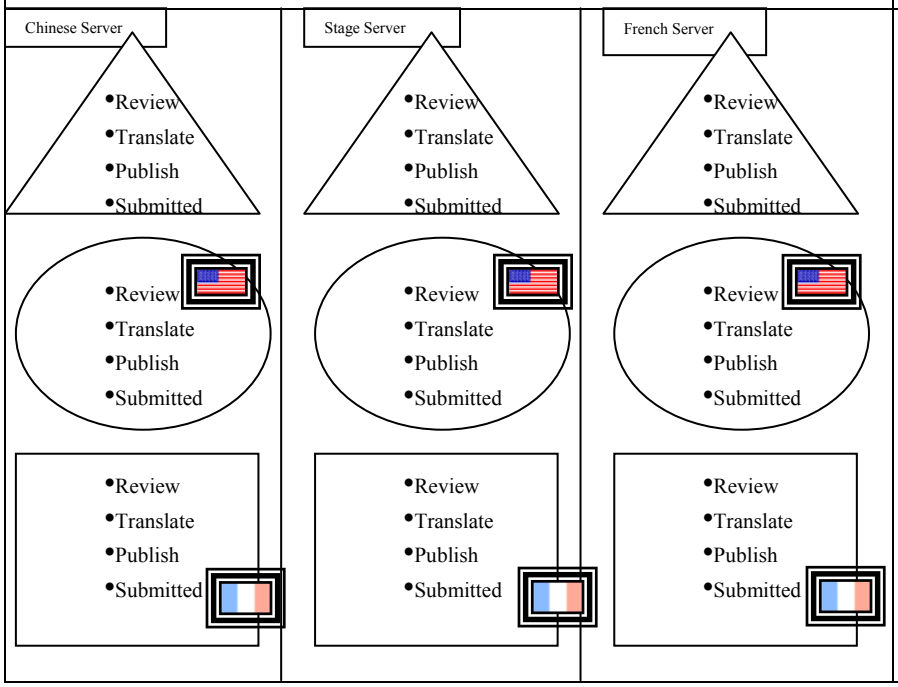


4. Replication. The abstract is replicated to all servers. As a result, there is a copy of the synchronized abstract in the English and French DBs of all servers in the GSSD network.

Figure 5.12b GSSD Global Workflow Process



5. On the French server, the French team opens the English DB and see that there is a French abstract that needs to be translated into English (under the heading "Abstracts for Translation). When they are done translating it into English, the abstract is marked as "Ready for Review."



6. Replication.

The translated abstract is replicated to all servers. As a result, there is a copy of the English abstract in the English DBs of all servers and a copy of the French abstract in the French DBs of all servers in the GSSD network.

Figure 5.12c GSSD Global Workflow Process

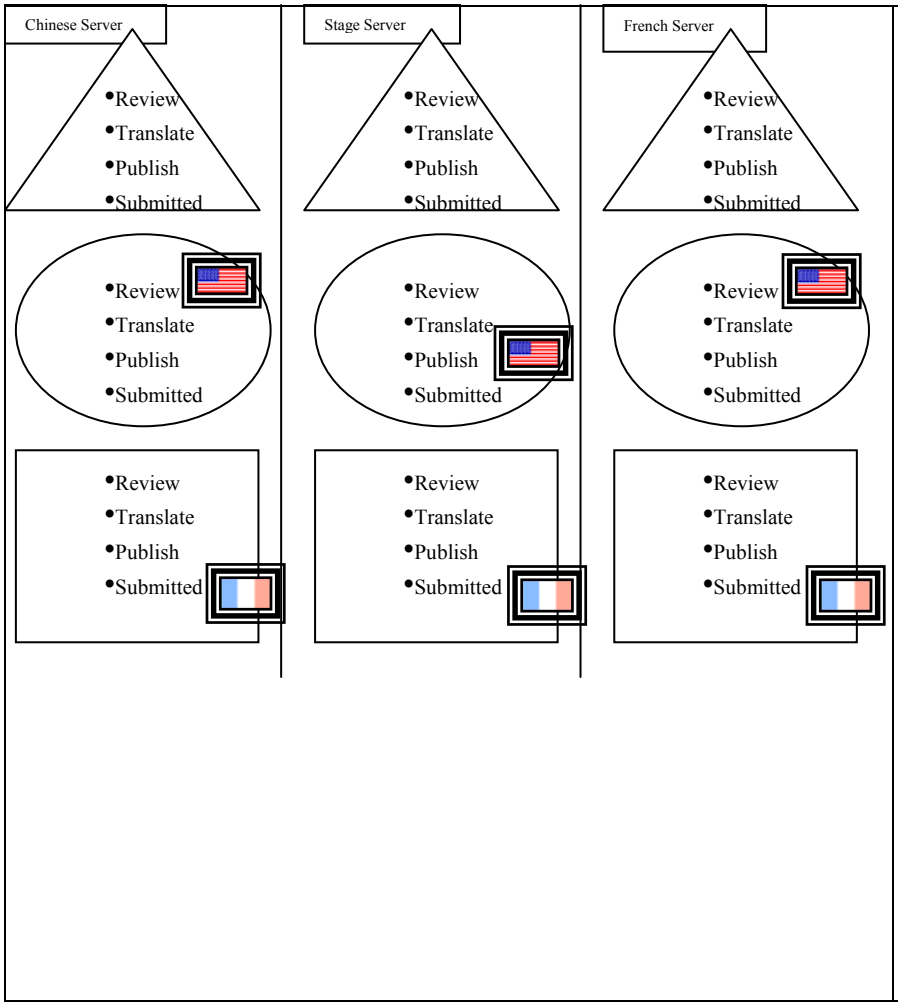
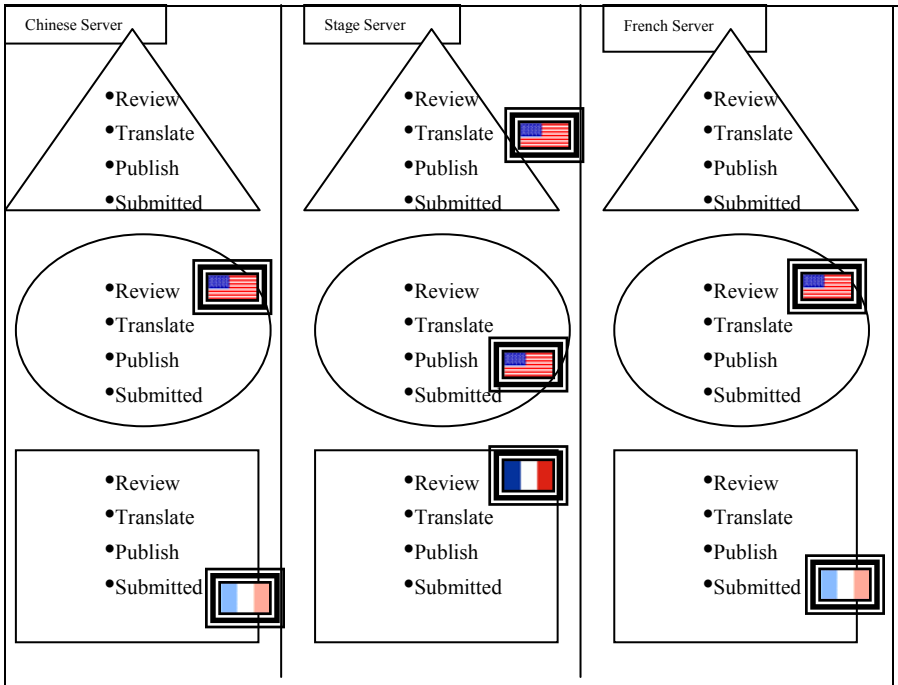


Figure 5.12d GSSD Global Workflow Process

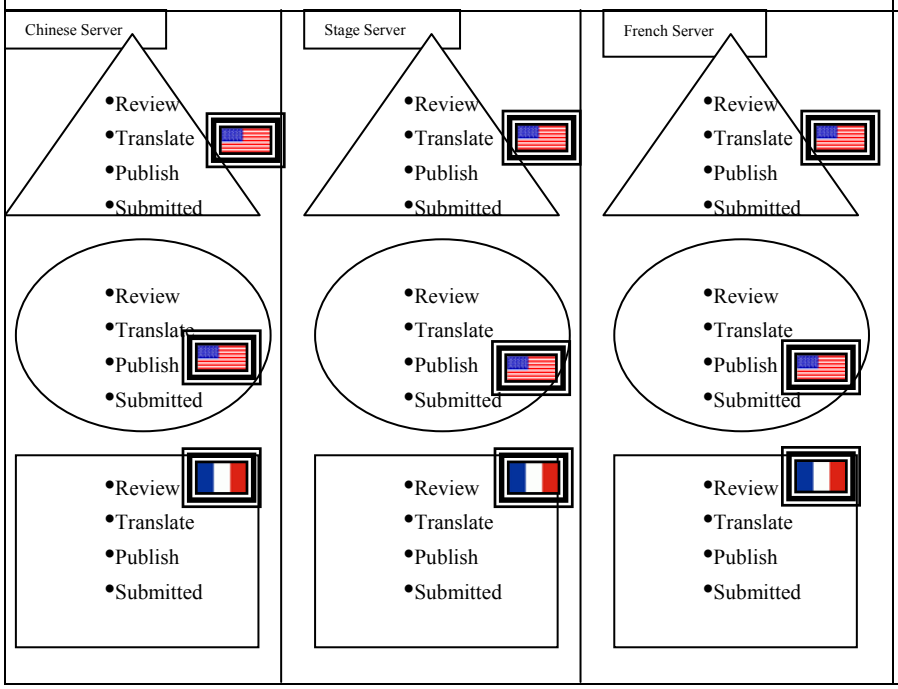


8. Synchronization.

This results in the following:

- A synchronized copy of the English abstract is placed in the remaining language DBs (Chinese) with the status of "Ready for Translation."

- The French abstract is also changed to "Ready for Review" status, with a link to the published English abstract and the note submitted by the English reviewer regarding changes made.



9. Replication.

The published English abstract is replicated to all servers. Also, there is a copy of the English abstract in the Chinese DBs of all servers under "Ready for Translation" and a copy of the French abstract in the French DBs of all servers under "Ready for Review."

Figure 5.12e GSSD Global Workflow Process

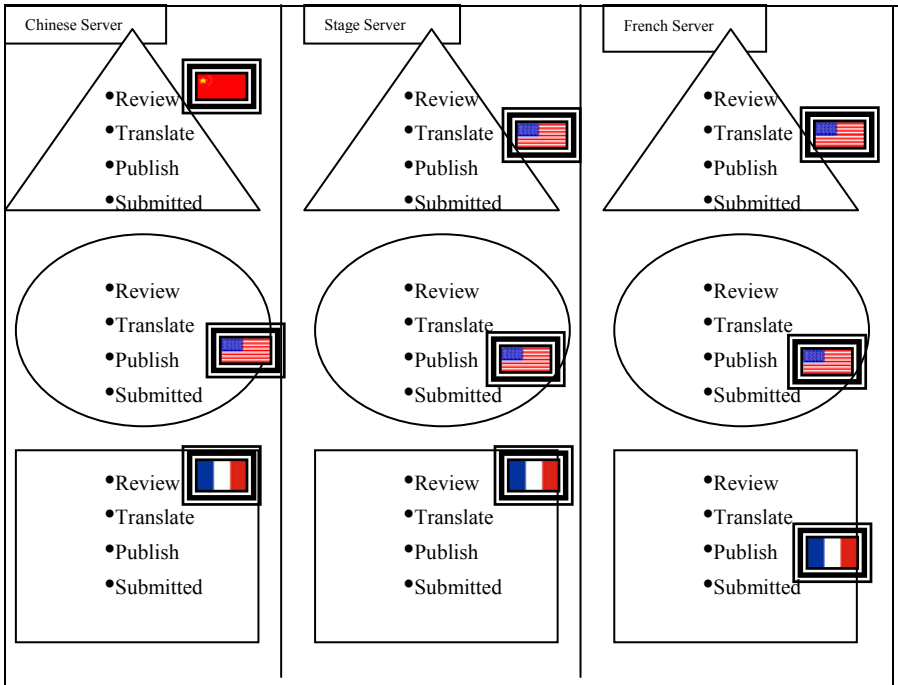
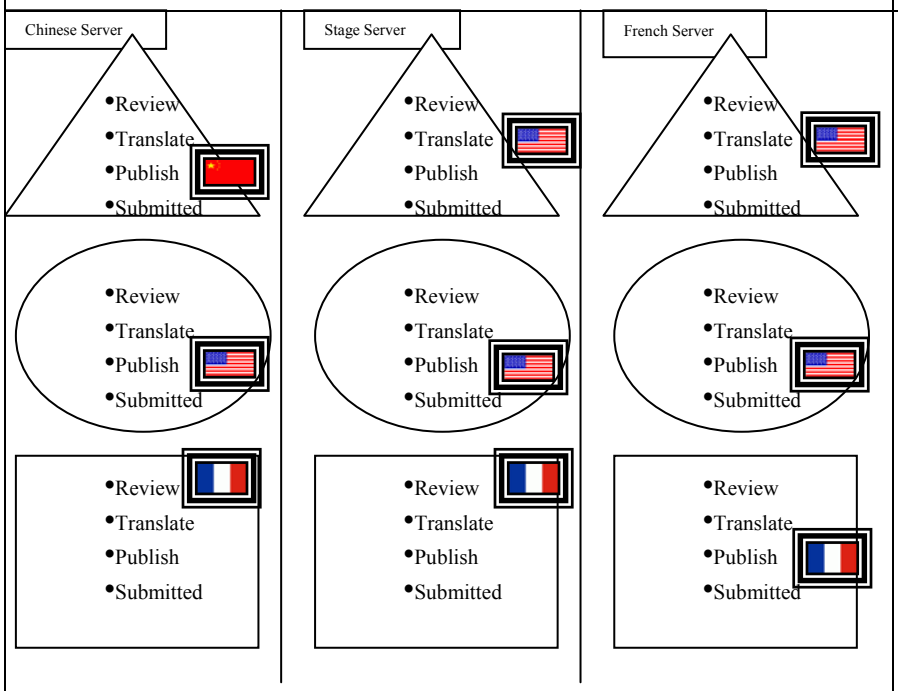
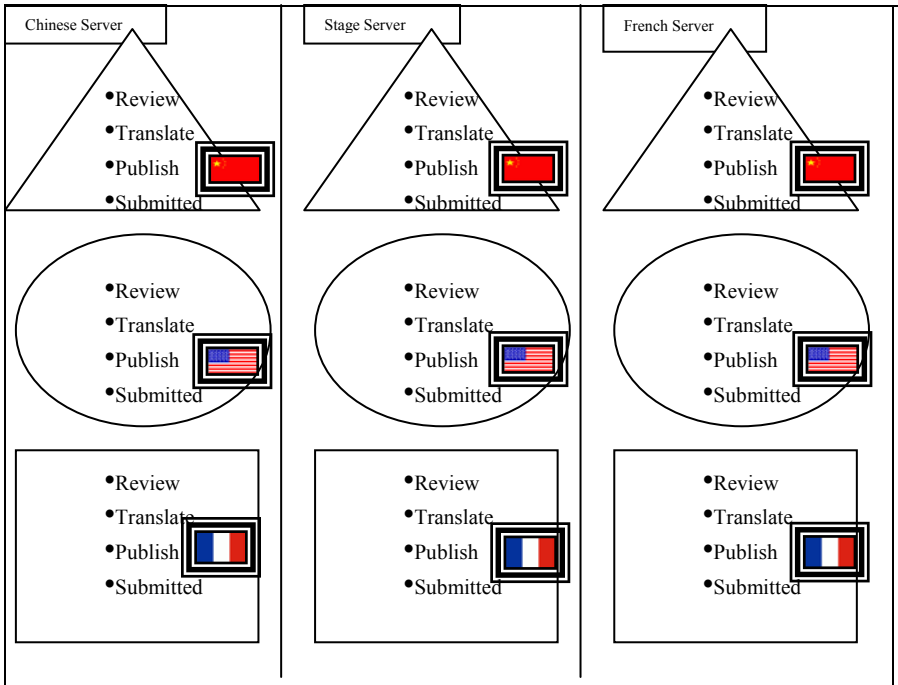
	10. The French see the French abstract in "Ready for Review" (no longer read-only), where they can now make changes to it and prepare it for publication. They check the English link in the abstract and the note submitted with the abstract to check for changes. Once the changes are made to match the English abstract, the French translation manager reviews and publishes the French abstract.
	11. The Chinese team opens the Chinese DB in China, finds the English abstract under "Ready for Translation," and translates the English abstract into Chinese. Once the abstract is translated, it is placed under "Ready for Review." 12. The Chinese translation manager reviews and publishes the Chinese abstract.

Figure 5.12f GSSD Global Workflow Process



13. Replication.

As a result of replication, the synchronized abstract is now distributed amongst all databases and published in all supported languages.

Even though these abstracts are located in different language databases and different servers, the GSSD system still recognizes them as the same synchronized abstract. Therefore, if the abstract is deleted at some point after publishing, all copies of that abstract will be subsequently deleted during the next synchronization and replication process.

The workflow process for this abstract is now complete.

Figure 5.12g GSSD Global Workflow Process

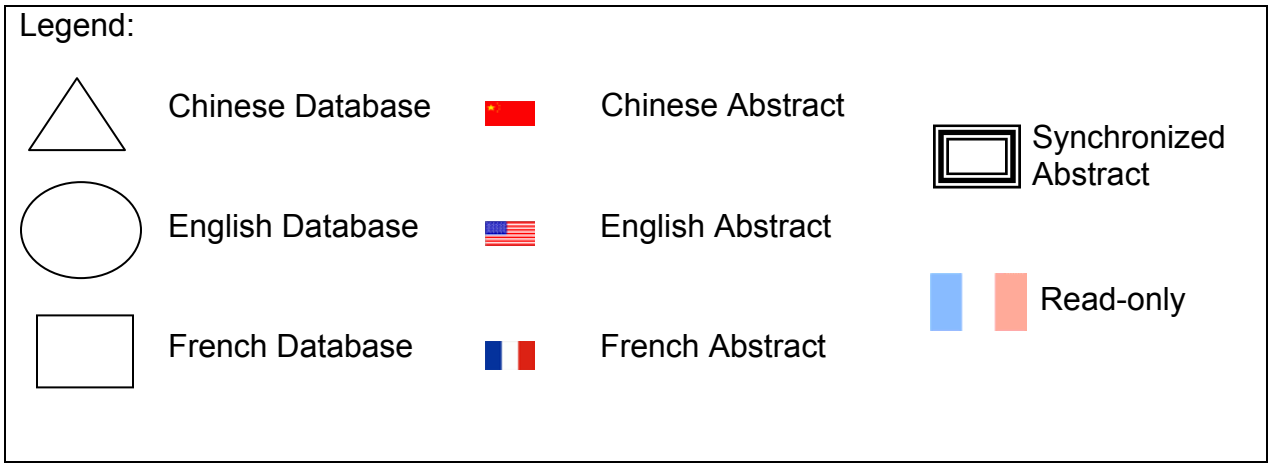


Figure 5.12h GSSD Global Workflow Process

The scenario depicted in Figure 5.12 illustrates the extent of collaboration and cooperation needed to ensure successful operation of GSSD. It not only identifies the necessary technical steps, but also demonstrates the requirements for human intervention throughout the workflow, and who has to do what, when, and how.

The detailed view provided in Figure 5.12 is intended to convey the complex and interdependent nature of the GSSD global workflow. Figure 5.13 provides a higher level view of the workflow process, where there are four basic components to the workflow, as indicated by the various colors. As shown by the figure below, the basic components of the global workflow are:

1. Pink-shaded section: the submitted abstract is routed to the local language site for content review and translation to English;
2. Blue-shaded section: the abstract is routed to the English review site for approval of the English version of the abstract;
3. Grey-shaded section: the English abstract is published and routed to all sites for translation into all other GSSD-supported languages;
4. Orange-shaded section: the abstract is published in all GSSD-supported languages and is available to all Web users through the GSSD search engine.

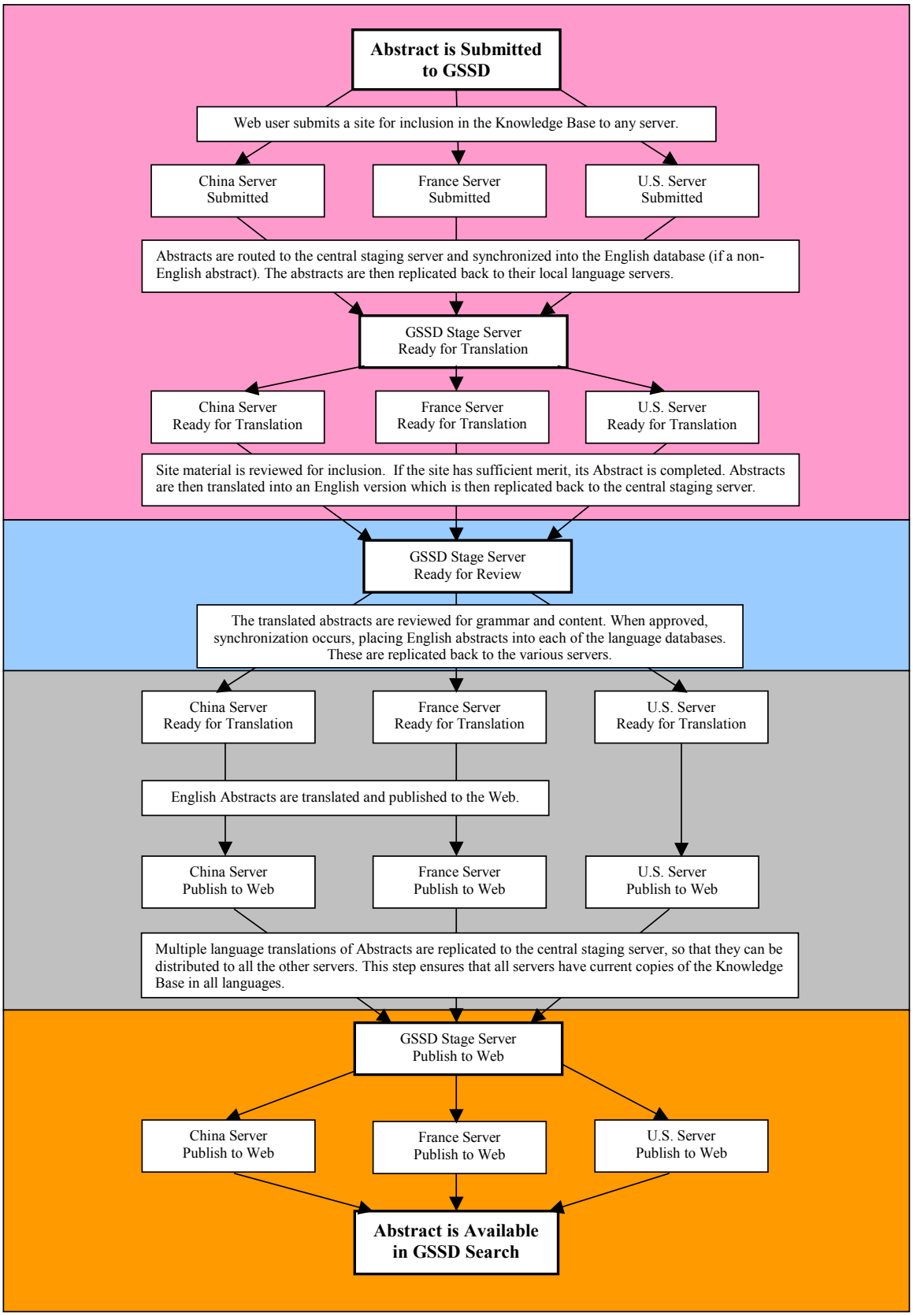


Figure 5.13 High Level View of GSSD Workflow

5.4.3 Workflow and the GSSD Knowledge Base

The successful operation of GSSD depends upon an efficient and effective workflow that enables content to be added to the knowledge base, which can then be extracted for use by GSSD users. The importance of workflow to the GSSD knowledge base is shown in Figure 5.14. The significance of the four components of the workflow illustrated in Figure 5.13 is highlighted in Figure 5.14.

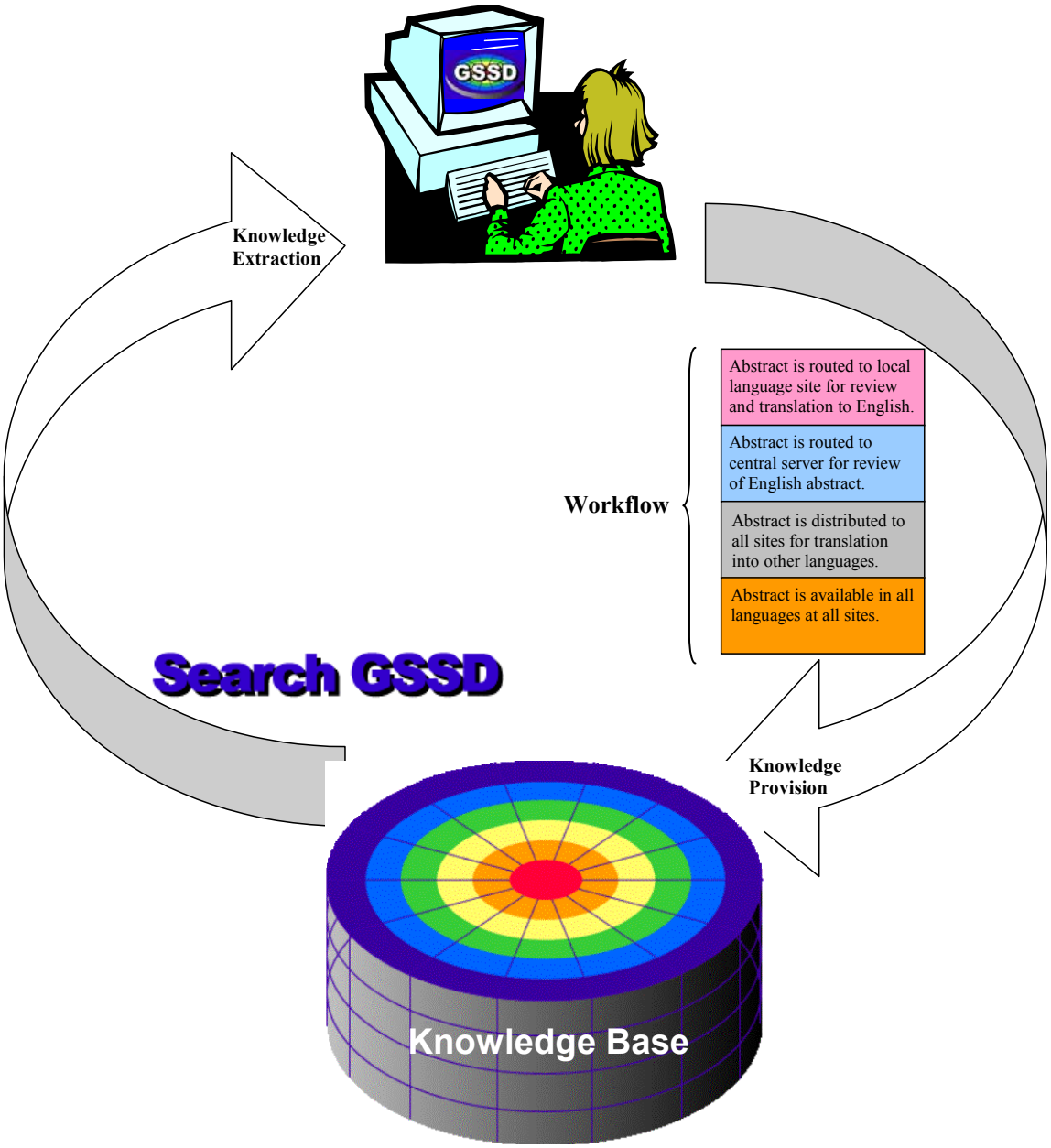


Figure 5.14 The Role of Workflow in GSSD Knowledge Base Dynamics

5.4.4 Other Potential Applications of Global Workflow

Due to the technical, organizational, and institutional challenges of GSSD administration presented earlier, a new framework for understanding global workflow processes and a unique workflow application have been developed. This new application and framework not only offer promise for new IT applications that promote sustainable development, but can also be utilized in other domains by groups who rely on this type of distributed and diverse workflow, such as multinational companies and international institutions.

This new global workflow methodology has wide applicability because it operates on the premise that a partnership or organization is distributed across multiple geographic locations and languages. During this era of globalization, these characteristics are becoming more and more prevalent and shaping the needs of complex, multinational, and international institutions.

Furthermore, this new global workflow is significant in the globalized era because it recognizes the importance of all partners and provides a platform to share diverse, locally-based perspectives. This "levels the playing field" for all contributors to a global workflow system, thereby enhancing the cooperative relationships and ensuring a more efficient and enriching workflow process.

6. Lessons Learned: Strategies for Developing Innovative IT Applications for Sustainable Development

6.1 GSSD Case Study: A Summary

The GSSD system contributes two significant findings to the research on IT and sustainability. First, it provides a valuable case study of an IT tool that successfully leverages positive IT linkages while addressing negative linkages associated with sustainable development. Second, an innovative global workflow application that was created as a result of the complex needs of the GSSD system demonstrates the flexibility and enabling power of IT. These two contributions are discussed in more detail in the following two sections.

6.1.1 GSSD Linkages

GSSD represents an IT application that leverages multiple positive linkages between IT and sustainability, by implementing the following capabilities:

- A useful and powerful tool that contributes to social empowerment through provision of knowledge about sustainability challenges and local initiatives;
- A platform for integrating a vast amount of valuable and relevant information related to various aspects of sustainability; and
- A knowledge networking architecture that utilizes the power of the Internet and related IT tools to strengthen and ensure continued evolution of the GSSD knowledge base.

Simultaneously, GSSD has been designed to counter significant negative linkages between IT and sustainability, as illustrated by the following characteristics:

- An operational definition for sustainability and a conceptual framework that prevents ambiguity and supports the analysis of inherently complex sustainable development issues;
- A well-defined and structured quality control process, which maintains and ensures high quality and reliability in the GSSD knowledge base while also allowing it to be populated in a distributed and collaborative manner.
- An effective set of capabilities to address digital and knowledge divide issues head on, such as:
    - Multilingual support and inclusion of a wider audience with diverse demographic and cultural characteristics;
    - An interface that enables the development and provision of local content, to help support local action initiatives related to sustainable development; and

- Extensive search capabilities available to everyone on a "non-premium" basis.

Therefore, GSSD provides an illustrative example of an IT project which has been designed and implemented to address sustainability challenges by relying on significant positive linkages and effectively hindering the impacts of key negative linkages.

6.1.2 Global Workflow Application

In addition to embodying many important positive IT linkages, GSSD has served as a "virtual global laboratory" for understanding the requirements for organization and management of a large scale, distributed, and diverse research initiative, with cross-national (countries in East Asia, the Middle East, and Europe) and cross-institutional (private, public, and international agencies) partners.

This thesis presented an innovative global workflow application that was developed and implemented as a result of experimenting within the "virtual laboratory" represented by the GSSD project. While operating in this environment, a series of critical organizational issues, institutional imperatives, and resulting technical challenges were identified. This thesis helps to address these issues by designing, implementing, and presenting a global workflow application. In other words, this research transformed the standard "out of the box" IT tool provided by IBM Lotus into a more powerful, customized, and effective platform for achieving the complex requisites set forth by GSSD.

On one hand, this workflow application helped to illustrate how the best IT tools still have a continuing need for human intervention, cooperation, and management in order to be successful. On the other hand, it is important to note that the invention of this new methodology for managing global workflow processes was made possible by IT advances. In other words, the capabilities of the IBM Lotus technology helped to drive and improve the functionality and capabilities of the global workflow process. Therefore, this new workflow methodology highlights the enabling and transformative potential of IT to meet complex and challenging sustainability goals.

6.2 Priorities for Advances in Global Knowledge Networks for Sustainable Development

While GSSD provides a rich global knowledge networking tool for sustainability, there is much room for improvement, particularly in the system's information streamlining and analysis capabilities. The following features would help advance GSSD's capabilities into a more robust tool for rigorous sustainable development research and policy making:

- **Automated information aggregation from various sources**. GSSD currently allows users to view data from a single abstract at a time. Analytic capabilities would be greatly improved if users could select data from multiple abstracts to

view at once.

- **Context mediation, which allows for the contextualization of content.** This functionality is related to the previous feature. Different sources of information provide various contexts for that information. Therefore, when the information is aggregated, there needs to be some functionality that can mediate the differing contexts and present the aggregated information in a consistent manner.

- **Greater customized information retrieval capabilities.** Currently, the GSSD search tool provides limited functionality for retrieval of GSSD content (see Figure 5.8). For example, the GSSD knowledge base points to a rich supply of data and indicators that are extremely valuable for analysis. The current search tool constrains the ability to effectively tap into these valuable data sets.

- **Sustainability knowledge ontologies.** Ontologies are the building blocks of current advanced IT tools which need to operate across various data sources and formats. Ontologies provide the ability to represent knowledge in a codified, organized, and reuseable manner. The availability of IT tools for developing ontologies provides a valuable opportunity to build upon the codification of sustainability topics already present in the current GSSD conceptual framework.

In order to implement these technical improvements, GSSD would benefit from the establishment of strategic collaborative partnerships. For example, the Context Interchange (COIN) project at MIT conducts cutting-edge research on information aggregation, context mediation, and ontological representation. A collaborative project between GSSD and COIN is currently being formulated[67], but there are still many other potentially productive avenues of cooperative research that can be pursued as well.

There are other projects, such as the World Bank's Development Gateway[68] and the International Institute for Sustainable Development's SD Gateway[69], which share many of GSSD's goals and offer promising opportunities for cooperation. GSSD has learned and benefited tremendously from its collaborative efforts with partners. By pursuing other types of strategic partnerships, GSSD has the potential to continue its evolution towards a robust IT-enabled mechanism for effectively tackling problems related to sustainable development.

[67] See Choucri et al (2001).
[68] See http://www.developmentgateway.org/ .
[69] See http://www.sdgateway.net/ .

7. Conclusion

7.1 Main Findings

The main contribution of this thesis is the development and implementation of a strategic methodology for assessing the impact of IT advances on prospects for sustainable development. The approach consists of two main elements: (1) analysis of the linkages between the IT tool and sustainability goals and (2) identification of critical institutional, organizational, and technical barriers and customization of the IT tool to address these issues.

7.1.1 Strategic Approach to Assessing IT Tools for Sustainability

When considering an IT-based approach to address sustainability challenges, the following elements should be considered.

7.1.1.1 Linkages

To assess whether or not an IT tool is appropriate for implementing sustainable development strategies, the following question should be asked: What are the linkages between the proposed IT tool and sustainability goals? The positive and negative linkages identified in Sections 3 and 4 of this thesis represent the type of analysis that should be conducted to answer this question.

7.1.1.2 Institutional, Organizational, and Technological Barriers

Once the significant linkages have been identified, the following question should be addressed: What are the relevant institutional, organizational, and technological barriers associated with meeting sustainability objectives, and how can the proposed IT tool help to alleviate these constraints? The global workflow application described in Section 5.4 represents the flexibility and enabling power of IT to meet complex requirements posed by institutional and organizational imperatives.

7.2 Further Research Needs

This thesis has provided a valuable approach to identifying strategies for leveraging IT advances to support and facilitate transitions toward sustainable development. Nevertheless, there is much research that still needs to be performed to further the efforts described here.

For example, the methodology presented in this thesis is based on qualitative assessment techniques. A further step would be to quantify the linkages methodology to enable easy comparison of positive and negative linkages. One potential approach would be to develop an Internet-based tool that allows a user to answer a set of questions regarding the proposed IT tool and provides the user with a "sustainability index" that summarizes the relevant positive and negative linkages and indicates the extent to which the IT application would enhance sustainability goals.

Another area of research is the compilation of a "best practices" database relevant to IT initiatives for sustainability. To date, there has been no such effort for industrialized nor developing country experiences. A comprehensive database of both types of cases would provide valuable insight, particularly for developing countries that have a lot to gain (or lose) from implementing IT initiatives. For example, what lessons can advanced countries offer to the developing world on the ways IT can be used to promote sustainable development? What have developing countries implemented successfully and how can similar projects be pursued in other developing countries? While the institutions described in Section 2 provide valuable case studies on IT projects, none of them have attempted to systematically analyze and codify these cases in a manner that would enable utilization by other organizations and researchers attempting to identify relevant "best practices."

Finally, a valuable area of research is to explore how advanced IT applications are relevant to the discussion of sustainable development. Most of the current literature, and the majority of this thesis, focuses on "common" IT tools, such as databases and the World Wide Web. However, there has been very little discussion about the potential role of advanced IT capabilities in sustainable development strategies. Artificial intelligence, intelligent devices, and peer-to-peer networks are examples of current state-of-the-art IT advances and offer the opportunity to address valuable research questions. For example, do these powerful devices have a role to play in sustainability initiatives? Do they address any limitations posed by more commonly used IT tools? Do they introduce new complications that could hinder progress towards sustainable development?

These research questions represent only a small fraction of the work that is yet to be done on the implications of IT for sustainability. This thesis avoids the careless classification of IT as a panacea while also cautiously challenging the dystopian notion of IT as a tool that causes more harm than good. In reality, IT advances represent a mix of these characteristics. Therefore, it is important to unbundle the problem and understand how to utilize the positive features of IT while avoiding the negative impacts on sustainable development. Moreover, the non-technical constraints associated with implementing IT initiatives in complex institutions and organizations should not be overlooked.

Therefore, IT has enormous potential to play a significant role in overcoming barriers to sustainable development if, and only if, potential limitations are identified and addressed effectively. The key task for researchers and policymakers is to assess how to utilize IT to advance developmental goals and minimize negative risks posed by this technology. It is important to remember that IT does not create the transformations needed for a sustainable society but it enhances the opportunities for humans to make these transformations. It allows us to effectively utilize the greatest natural resources available for sustainable

development: *human intelligence, creativity, and ingenuity*.

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