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TECHNOLOGICAL IMPEDIMENTS TO B2C ELECTRONIC COMMERCE: AN UPDATE

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ABSTRACT

In 1999, Rose et al. identified six categories of technological impediments inhibiting the growth of electronic commerce: (1) download delays, (2) interface limitations, (3) search problems, (4) inadequate measures of Web application success, (5) security, and (6) a lack of Internet standards. This paper updates findings in the original paper by surveying the practitioner literature for the five-year period from June 1999 to June 2004. We identify how advances in technology both partially resolve concerns with the original technological impediments, and inhibit their full resolution. We find that, despite five years of technological progress, the six categories of technological impediments remain relevant. Furthermore, the maturation of e-Commerce increased the Internet's complexity, making these impediments harder to address. Two kinds of complexity are especially relevant:

- evolutionary complexity, and
- skill complexity.

Evolutionary complexity refers to the need to preserve the existing Internet and resolve impediments simultaneously. Unfortunately, because the Internet consists of multiple incompatible technologies, philosophies, and attitudes, additions to the Internet infrastructure are difficult to integrate. Skill complexity refers to the skill sets necessary for managing e-Commerce change. As the Internet evolves, more skills become relevant. Unfortunately, individuals, companies and organizations are unable to master and integrate all necessary skills. As a result, new features added to the Internet do not consider all relevant factors, and are thus sub-optimal.

Keywords: technological impediments, practitioner, e-commerce, Internet

I. INTRODUCTION

Through a meta-analysis of trade press articles from 1994-1999, Rose et al. [1999] identified six categories of technological impediments to progress in electronic commerce (e-Commerce):

1. *Download Delays*: Users face prohibitively long wait times to access e-Commerce information and applications.
2. *Interface*: Current user interfaces inhibit sensory interaction with e-Commerce applications.
3. *Search Problems*: Finding relevant e-Commerce information or applications is difficult for users.
4. *Inadequate Measures of e-Commerce Success*: Owners cannot effectively evaluate the success of their applications.
5. *Security*: Malicious individuals employ e-Commerce technologies to perform unallowed tasks, or extract restricted information.
6. *Lack of Standards*: Users and developers encounter difficulties accessing, using, and integrating diverse e-Commerce applications.

Five years elapsed since the analyses in the original article, and technological impediments continue to hinder e-Commerce adoption. A 2003 US survey of 80 million individuals who did not use the Internet indicated that 17% refused to do so because of technical difficulties [Philipkoski, 2003]. The present research updates the original Rose et al. study with a review of trade press articles from 1999-2004. Our specific research objectives are to:

- Discuss the progress made in resolving concerns with the above six technological impediment categories.
- Describe unresolved issues within the six technological impediment categories.
- Synthesize unresolved issues since 1999 and identify reasons for the lack of resolution.

The paper proceeds as follows. Section II discusses our review methodology and describes how we sampled and analyzed articles. Section III discusses resolved and unresolved issues surrounding the six technological impediment categories. Section IV synthesizes the unresolved issues and argues that the technological impediments are unlikely to be resolved because the Internet is now a complex, and unmanageable space. Section V discusses limitations.

II. RESEARCH METHODOLOGY

Our research adopts a methodology similar to the original work [Rose et al., 1999]. We pointedly concentrate on issues and articles relevant to practitioner rather than research communities. However, we have refined the methodology in the original paper, incorporating enhancements when they do not contravene the spirit of the original article. For example, this study employs trade press articles from three sources instead of the one source used in the original. Namely, we sampled trade press articles for the period June 1999- June 2004 from the sources: (1) ACM Technews, (2) Lexis-Nexis, and (3) ABI Inform.

ACM Technews¹ is an e-mail service begun in December 1999 that summarizes computer science-related practitioner articles from all over the world. All summaries in the ACM Technews database were reviewed manually to identify relevant articles. A total of 628 articles were identified from this source.

¹ ACM Technews is an electronic newsletter issued three time per week via e-mail to members of the Association for Computing Machinery.

We used the “Guided News” feature of Lexis-Nexis² to identify relevant articles from that database. In contrast to the “Quick News Search” feature, which only allows access to two years worth of articles, the Guided News feature enables access to all articles. However, to use “Guided News,” a user must specify: (1) a subcategory of news articles to search for, (2) up to three search terms, (3) the location in the news article where those terms can be found, and (4) a time period to investigate. We retrieved articles from two categories: (1) General News/Major Papers, and (2) General News/Magazines and Journals. Lexis-Nexis also restricts queries so that no more than 1000 ‘hits’ can be returned. Attempts to produce broader queries are rejected by the system. Articles retrieved included search terms in the headline, lead paragraph, or terms/keywords section of the article. Searches were restricted to articles “within the past five years.” The identical keywords employed for the Lexis-Nexis search were then used to query the ABI Inform³ database.

Some databases rely on the order of search terms to facilitate result retrieval, and hence produce different results when the order of search terms is changed. To ensure this was not the case, we executed various permutations of our first three searches on both the Lexis-Nexis and ABI Inform databases. The results were identical, regardless of the search term order employed. Table 1 (a)-(f) presents the keywords, and results of each search.

Table 1. Search Results for Technological Impediments

a. Download Delay			
Keywords	News Category	# Articles Retrieved	# Articles Used
Download and delay	General News/Major Papers	53	18
	General News/Magazines and Journals	41	10
	ABI Inform	28	15
Download and speed and faster	General News/Major Papers	130	5
	General News/Magazines and Journals	77	17
	ABI Inform	124	5

b. Interface			
Keywords	News Category	# Articles Retrieved	# Articles Used
Interface and internet and browser	General News/Major Papers	103	10
	General News/Magazines and Journals	392	21
	ABI Inform	187	16
Interface and internet and mobile	General News/Major Papers	62	3
	General News/Magazines and Journals	263	18
	ABI Inform	130	13

c. Search Engines			
Keywords	News Category	# Articles Retrieved	# Articles Used
Search engine and internet and algorithm	General News/Major Papers	19	2
	General News/Magazines and Journals	29	4
	ABI Inform	22	6
Search engine and internet and interface	General News/Major Papers	48	3

² Lexis-Nexis is an online archive of articles, magazines, and legal articles dating from 1986. Lexis-Nexis is a service of Reed-Elsevier.

³ ABI Inform is a database of academic and practitioner articles dating from 1971 collated by Proquest. The database is available both online, and as a CD compilation.

	General News/Magazines and Journals	76	3
	ABI Inform	46	8
Search engine and internet and queries	General News/Major Papers	164	5
	General News/Magazines and Journals	75	9
	ABI Inform	85	5
Search engine and internet and hits	General News/Major Papers	425	9
	General News/Magazines and Journals	142	3
	ABI Inform	53	19
Deep web	General News/Major Papers	17	4
	General News/Magazines and Journals	4	1
	ABI Inform	17	10

d. Web Metrics

Keywords	News Category	# Articles Retrieved	# Articles Used
e-commerce and metrics	General News/Major Papers	17	2
	General News/Magazines and Journals	37	6
	ABI Inform	48	16
Web bug	General News/Major Papers	32	4
	General News/Magazines and Journals	20	2
	ABI Inform	37	15
Server log	General News/Major Papers	4	1
	General News/Magazines and Journals	28	9
	ABI Inform	50	17
Cookie and e-commerce	General News/Major Papers	14	1
	General News/Magazines and Journals	26	3
	ABI Inform	43	15
Spyware	General News/Major Papers	372	5
	General News/Magazines and Journals	234	2
	ABI Inform	318	9

e. Security

Keywords	News Category	# Articles Retrieved	# Articles Used
Malware	General News/Major Papers	46	7
	General News/Magazines and Journals	177	3
	ABI Inform	64	18
Spam and e-commerce	General News/Major Papers	56	8
	General News/Magazines and Journals	41	6
	ABI Inform	39	13
Virus and e-commerce	General News/Major Papers	67	6
	General News/Magazines and Journals	46	2
	ABI Inform	82	30
Distributed denial of service	General News/Major Papers	50	9
	General News/Magazines and	148	20

	Journals		
	ABI Inform	158	68
Privacy and e-commerce and data mining	General News/Major Papers	7	3
	General News/Magazines and Journals	6	1
	ABI Inform	5	3

f. Standards

Keywords	News Category	# Articles Retrieved	# Articles Used
Standard and e-commerce	General News/Major Papers	516	40
	General News/Magazines and Journals	749	36
	ABI Inform	1084	290

Articles identified as relevant and interesting were collated based on reporting author, and publication source. Each article was coded as “download,” “interface,” “search engine,” “measure,” “security,” or “standard.” Open coding techniques [Strauss and Corbin, 1990] were then used to identify issues and concerns within each technological impediment category. Because our research attempted a broad survey of technological impediments, each article was coded in its entirety. Little effort was spent on micro-analysis [Strauss and Corbin, 1990]. Table 2 identifies similarities between the methodology employed in this research and Rose et al. [1999], while Table 3 identifies differences.

Table 2. Methodological Similarities Between Rose et al. [1999] and This Research

Focus on trade press articles.
Articles obtained from electronic database.
Initial sample obtained using keywords
5 years of articles reviewed.
Articles reviewed presented as attached bibliography.

Table 3. Methodological Differences Between Rose et al. [1999] and This Research

	Rose et al. [1999]	This Research
<i>Database</i>	Only ABI Inform database employed	Three databases employed: (1) ABI Inform, (2) Lexis Nexis, (3) ACM Technews
<i>Analysis Window</i>	1994-1998	June 1999-June 2004
<i>Focus</i>	Search for all articles on technological impediments	Special focus on six categories identified in Rose et al. [1999]
<i>Coding Scheme</i>	Not discussed	Open coding

In total, over 1500 articles were obtained, coded, and analyzed for this study. The list of articles is presented in the Bibliography.

III. PROGRESS AND UNRESOLVED ISSUES

This section reviews progress and unresolved issues relevant to the six technological impediment categories discussed in Rose et al. [1999].

DOWNLOAD DELAYS

Download delays impact electronic commerce in a number of ways.

1. Internet users avoid slow-to-download media [Rose et al., 1999]. For example, Internet users are more reluctant to view movies than still images online.
2. Download delays proscribe business' ability to deliver content to customers. For example, people might be more willing to buy fruit online if they could observe the fruit live via web cam [Rose et al., 1999].
3. Some emergent technologies are sensitive to variations in download speed. For example, when the download speed of video-based applications vary too greatly, jitter results. In jitter, images "jump" on the screen [Anonymous, June 24, 2004]. Similarly, online games are affected, because a delay impacting a single-user of a multi-user game can put that user at a gross disadvantage [Wearden, 2004].
4. Download delays in strategic areas (such as Internet backbones) decrease the usability of the Internet for large numbers of individuals across multiple applications.

In Rose et al. [1999], a graphical model was used to identify various forms of download delay. Figure 1 extends that model in three ways:

1. we identify areas where progress was made to ameliorate delay (denoted with '+'),
2. we identify areas where the situation has deteriorated since the 1999 publication of the original article (denoted with '-'), and
3. we identify new factors influencing download delay (denoted in blue).

The remainder of the section discusses this extended model. The model is shown in Figure 1.

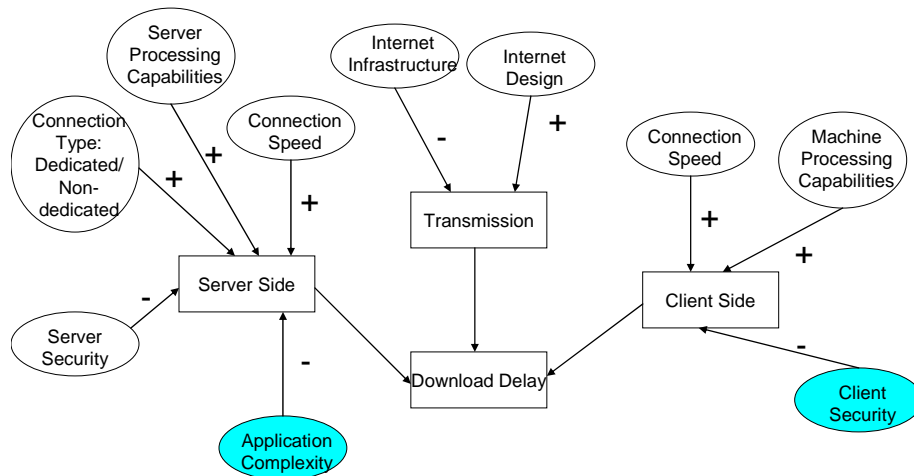


Figure 1: Factors Affecting Download Delay

Progress

Many-to-most Internet users can now access the Internet faster than five years ago. A 2004 survey found that broadband access is available to 42 percent of U.S. Internet users at home, and 77 percent at work [Anonymous, 2004]. Broadband access is even further developed in other countries such as Korea and Japan. Moreover, new technologies can improve latency. For example, traditional telephone lines (i.e., twisted pair) are now able to support 10 Gbps traffic [Hamblen, 2004, Mearian, 2004, Reardon, 2004], and enhancements to basic caching [Hadenius, 2004], routing [Anonymous, August 12, 2002], transmission [Kroeker, 2004, Martin, 2004] and server balancing [Anonymous, April 15, 2004] software likewise improved speed. Similarly, faster, more powerful computer processors and primary and secondary storage devices are available on the market.

One novel approach likely to improve access speeds further is peer-level computing such as peer-to-peer networks or grid computing. In peer-to-peer computing, files or data are shared across processors on a network. Peer-to-peer networks are especially useful for distributing commonly requested data. Unlike traditional client-server networks where all requests for data are sent to one or a small group of servers, in peer-to-peer computing, data is requested from any computer that has it. Thus, data requests and data transfers are distributed through the network [Anonymous, August 21, 2003, Hadenius, 2004].

In grid computing, processing capacity is distributed across the computers connected to the network. Thus, user A can leverage user B's processing power if user B's computer is idle [Barker, 2003, Terdiman, 2004]. Grid computing did not yet impact e-Commerce in 2005, but is used in scientific settings such as the [Seti@Home](#) project. In [Seti@Home](#), volunteers devote their spare computing capacity to facilitate the search for intelligent extraterrestrial life [Graham-Rowe, 2003]. From an e-Commerce perspective, some companies such as Google are experimenting with grid computing (e.g., <http://toolbar.google.com/dc/offerdc.html>).

Unresolved Issues

Unfortunately, while transmission and processing speeds improved greatly, users do not necessarily experience faster transmissions. This outcome is especially regrettable, given that user perceptions of access speeds, and not the actual access speeds, influence user behavior [Hopkins, 2003]. At least five factors continue to impact user actual or perceived download times negatively:

1. *Increased Application Complexity.* Improvements in access speeds are, to a large degree, offset by the increased complexity of e-Commerce applications [Head, 2003]. Modern e-Commerce applications include multiple layers of security [Berlind, 2003], and new features that fill available bandwidth. For example, flash and other forms of animation are now common on corporate home pages. Similarly, tracking technologies installed both at the client and server such as single-pixel images and spyware consume processing power leading to a slower perceived shopping experience. Single-pixel images and spyware are discussed in the metrics section.
2. *Central Load Distribution.* Most e-Commerce applications were developed and released in specific geographic locales (e.g., California). As a result, traffic on the Internet is distributed unevenly. Certain "backbone" computers absorb most traffic, while other computers in less central locales sit idle [Sharwood, 2003]. The load distribution problem is especially critical given that many new users (e.g., users from developing nations) are not situated near these backbones. Some companies like Akamai (www.akamai.com) replicate business websites to servers on the "edge" of the Internet. This strategy decreases traffic congestion on the major backbones. However, such replication creates other problems such as lack of consistency between versions of web applications mounted on separate servers.
3. *Vulnerable Infrastructure.* The current Internet infrastructure contains numerable points of failure. For example, the August 14, 2003 blackout that disrupted power to the Northern US States and Canada brought down over 9700 networks and affected millions of users [Lemos, 2004]. Similarly, in February 2001, damage to a single undersea cable caused huge disruptions in Internet traffic between the US and Asia [Anonymous, February 9, 2001]. This vulnerability is especially ironic given that the original design intent of the Internet was to protect against such massive failures (http://livinginternet.com/ii_darpa.htm).
4. *Final-mile bottlenecks.* Even in areas where broadband is available, the infrastructure is insufficient to provide true broadband. Digital Subscriber Line (DSL), the broadband service available from the telephone company only works if the subscriber is close to a major trunk (typically 12,000 to 18,000 feet) [Marek, 2001]. Furthermore, the quality of

the physical line is important. Older telephone lines often cannot support DSL. Cable modems, the cable company alternative, are often distributed across multiple users. As a result, cable service tends to suffer during peak traffic periods [O'Donnell, 1999]. Wireless broadband service, often the only service available to rural areas, involves numerous problems.

- Wireless service is vulnerable to weather conditions and physical obstruction. Storms, passing airplanes, or intervening buildings can reduce the efficacy of wireless service(<http://h71036.www7.hp.com/hho/cache/8931-0-0-225-121.aspx>).

- Satellite-based broadband service is constrained by the physical distance between the satellite and the home. The resulting small delays (typically half a second) can impact latency if large numbers of messages must be communicated in a short period of time (<http://www.lonestarbroadband.org/technology/satellite.htm>).

- Alternate forms of wireless broadband, such as 3rd generation services are plagued by numerous problems such as slow rollout and legal disputes. As a result, the adoption of 3G services has been slow [Rotter, 2002]. 3G services are not so ideal for rural areas, because wireless connections to remote areas require large inputs of power.

5. *Cost.* In many places, broadband remains an expensive proposition. Regulatory costs establish a lower bound on how much broadband ISPs can charge, at least in the US [Hu, 2004]. Also, while there are many broadband ISPs, only a few provide service in a given region. The result is increased supplier power [Spanbauer, 2003].

As a result of these factors, broadband adoption in the US has been slower than anticipated [Gross, 2003]. The US is ranked only 11th in broadband adoption. In contrast, in South Korea (1st) the number of subscribers is 70.5 per 100 people. In Hong Kong (2nd), the number is 50.3 [Anonymous, September 15, 2004]. In addition, the broadband service offered in the US is inferior to service offered in countries with a higher adoption rate [Mark, 2004]. The statistics thus tend to inflate US adoption rates:

"In Japan, for as little as \$10, consumers receive broadband service at 8,000 kbps. In Korea, consumers receive 10,000 kbps for the same price that we pay for 1,500 kbps... Why, then, is the FCC still collecting data about 200 kbps service and calling it broadband? (Commissioner Michael J. Copps, Dissenting opinion, Fourth Annual Report to Congress on Broadband Deployment)?"

It is clear that download delays are still a major problem in many parts of the world. We documented hindrances in the US. Obviously, the same conditions apply, and even more so, in the developing world and least developed countries.

INTERFACE

Interface issues, termed "limitations" in the Web interface in Rose et al. [1999], restrict e-Commerce growth in three ways.

1. The sale of particular products is made more challenging. For example, it is difficult (but not impossible) to sell fruit on the Internet, because the client cannot touch, taste, or see the fruit being sold [Rose et al., 1999].
2. Entire classes of consumers (e.g., the disabled) are denied access to e-Commerce because of interface restrictions.
3. Interface limitations result in less than optimal responses on the part of many customers. Some user interfaces even encourage errors or mistakes that can lead to disastrous consequences. For example, instead of entering a \$10 contest,

Robert Guinther mistakenly entered a \$100 international poker tournament. Fortunately, in this case, Robert won the tournament [Anonymous, July 4, 2005].

Progress

Substantial improvements have been made in the interface experience for e-Commerce users.

Using the Handmirror Metaphor. For mobile users, Origo developed a system for mapping HTML pages onto hand-held telephone screens.⁴ The system uses the “handmirror” metaphor. When users retrieve a page, they see a portion of it on their screens. Users tilt their handphones to see other portions of the page, and zoom in or out by moving their handphones closer or further away from their bodies [Anonymous, 2002].

Translation. Translation systems are being developed to enable users conversant in diverse languages to understand each others' websites [Farah, 2003]. For example, Google offers a language translation service at http://www.google.com/language_tools.

Visual Immersion. Work underway on visually immersive environments includes avatars (i.e., graphical surrogates of a user existing in a virtual world) [Johnson, 2003, Kushner, 2004], wraparound screens [Karif, 2004], and virtual reality systems [Anonymous, May 12, 2003]. Audio data quality is substantially enhanced so that blind users can use sound cues in-lieu of sight [Salkever, 2004]. Work is also being carried out to transmit the sense of smell [Anonymous, April 2, 2004] and touch [Catchpole, 2004] over the Internet.

3-Dimensionality. Perhaps the greatest advances are in the area of 3D rendering in 2D space. Many virtual worlds such as those in games like Doom, Everquest and Ultima Online support environments so realistic that miniature virtual economies formed, that have real world cash values [Anonymous, October 21, 2002]. For example, virtual castles in Ultima Online can fetch USD 1,200 [Dibbell, 2003].

User Requests. Developments also exist to enhance the transmission of user requests. Mobile devices such as handphones are being reworked for use as e-Commerce interfaces [Maney, 2003]. Similarly, many test applications accept images as input. For example, some engineering search engines allow the user to sketch a part to search for [Schwartz, 2003, Sherman, 2004]. GPS systems allow the user to take a snapshot of a building to ascertain the user's location [Randerson, 2004].

Video and Audio Data. Higher quality transmission lines also mean that video and audio data can be transmitted more easily [Anonymous, February 12, 2004, Villano, 2004]. The rapid increase in digital piracy, especially of music and movies is testimony to such progress [MacRae, 2002].

Unresolved Issues

Most of the interface technologies just discussed are still in the experimental stage, and many will be unavailable for e-Commerce use in the next five to ten years (or more). In addition, the following limitations exist with current interface technology.

Network Externalities. Businesses must overcome network externality problems to encourage adoption of new interface technologies. It is not profitable for a business to reengineer its website to incorporate an interface that is not available on anyone's browser. Conversely, users are reluctant to buy interfaces that e-commerce websites do not support. New interfaces that exploit touch, smell or taste also increase consumer vulnerability. Consumers might be unwilling to purchase a device that emits an unexpected smell every time a particular pop-up ad appears. Inexpensive commercial technologies to transmit taste and smell exist. For example, Telewest

⁴ We use the term handphone as a shorthand for such telephones.

sells a PC-compatible “scent dome” for under USD 500 [Anonymous, November 11, 2004]. However, few people adopted this technology, which gives credence to the concerns identified here.

Using the Senses. Existing interfaces continue to make e-Commerce difficult. Fully three in four disabled Americans stay offline [Philipkoski, 2003]. This statistic is not surprising, especially given that existing technologies rely on particular senses. For example, CAPTCHAs (i.e., Completely Automated Public Turing test to tell Computers and Humans Apart) are used to prevent autonomous agents from obtaining resources or access to data. Many CAPTCHAs rely on human vision. For example, the most commonly available CAPTCHA, Gimpy, requires the user to identify a word that is altered graphically. Visually-impaired users are unable to easily view such sites [Festa, 2003]. Note that while visually-impaired users cannot ordinarily view websites, they can do so with special technological aids (e.g., visual-to-audio translators). CAPTCHAs fool these aids, thereby making viewing impossible.

Mobile Computing. Mobile computing interfaces especially are difficult to use because:

1. Most mobile devices provide small screens, and constrained user interfaces. For example, the typical Internet-enabled handphone has a numeric keypad and several screen-control keys that use up most of the available space on the phone.
2. Much of the mobile device design logic focuses on miniaturization and minimal power consumption. Thus, low processing capabilities and small memories constrain the kinds of features that a mobile user-interface can have.
3. Because of the great deal of noise common in wireless communication, less bandwidth is available for sending user-interface related messages because more of the signal must be devoted to carrying messages of importance [Prochak, 2000].

3-Dimensionality. Commercially available 3D interfaces do not exist. While existing technology allows 3D images to be mapped to 2D screens, it is not possible for most users to view a truly 3D object. True 3D image technology such as that sold by Teleportec may cost upwards of USD 250,000 per unit [Cardwell, 2002].

Web Navigation. Available web page navigation tools are incompatible with other kinds of technology. For example, many users are accustomed to using the “Back” button to return to a previous web page. However, the back button is incompatible with modern web security features in that it allows a third party to view sensitive user data when they are away from a terminal [Bell, 2003].

Many available navigation tools also do not mesh with human behavior. For example, most browsers only provide two ways to store a website URL: via electronic bookmarks (e.g., the “favorites” option in Internet Explorer) or temporarily by date in the browser cache. However, the methods humans employ to retrieve information are often linked to the way the information is expected to be used. For example, a user that requires a web page while traveling, might send the URL to him/herself via e-mail. The two existing methods for storing URLs do not consider intended use of URLs as part of their retrieval mechanisms [Anonymous, December 17, 2003].

Controlling Human Behavior. The existing web infrastructure makes it problematic to control user behavior. Most customers visit an e-Commerce site using a web browser. The e-Commerce site itself is distributed across multiple web pages that the customer either navigates by using the mouse, or visits by typing in the URL. The latter action is problematic for e-Commerce companies, because it is difficult to model the unintended consequences of mistyped URLs. A customer could accidentally gain access to restricted information, or could duplicate an already processed transaction [Bisson, 2003].

SEARCH

Effective search capabilities are critical for e-Commerce success because customers must be able to obtain information and products. While customers could visit an e-Commerce site directly, sometimes the site's Internet location is not obvious [Rose et al., 1999]. Furthermore, customers sometimes want to integrate products from multiple vendors, and thus must identify third-party companies that perform such integration. Customers also desire information like third-party evaluations of products to make more informed choices.

Users of web search engines typically adopt two practices that make the development of good web search engines difficult.

1. Users frequently use undescriptive queries of one or two words [Jansen et al., 1998, Silverstein et al., 1999]. Words used often can be associated with numerous contexts, and thus web documents unrelated to the query's intent are normally retrieved.
2. Most users only work with the first 10 search engine results [Hopkins, 2003]. However, because only one or two words were employed in the query, such results are frequently not accurate.

Progress

Commercial search engine developments focused primarily on helping users elaborate their queries [Anthes, 2004]. Such work proceeded along five main lines:

1. *Offloading processing to the client (user) machine.* Offloading enables the search engine to personalize itself based either on client input or observations of client behavior [Bazeley, 2004, Delio, 2003]. For example, many websites store customer transaction histories and use cookies to track the customer over multiple visits.
2. *Alternative Interfaces.* In the traditional web interface, the user keys in terms which the search engine employs to produce results. Some work modifies the interface to encourage other styles of querying. For example, some search engines allow the user to sketch the image to be retrieved [Sherman, 2004]. Still other work blends navigation with search. Vivismo (<http://vivisimo.com/>) clusters results based on common keywords [Haggood, 2003]. Users navigate through the clusters to refine the search. In ScentTrails, the search engine reports not only the relevance of a particular page *A*, but also the relevance of web pages linked to *A*. This information enables the user to determine whether page *A* focuses on a topic, or only discusses it tangentially.⁵
3. *Reorganizing Web Data.* Most of these projects attempt to mark up files to be retrieved more easily by a search engine. For example, Annodex is a technology for marking multimedia files with descriptive text [Whitfield, 2003]. Because manual annotation is tedious, some tools automatically transform voice annotations to text [Ananthaswamy, 2004]. The semantic web is a project to tag all web pages with metadata to enhance search [Lee, 2004].
4. *Personalization:* Innovative work was also done to leverage personal information collected from the user. Eurekster (www.eurekster.com) attempts to maximize search relevance by categorizing users to user-defined groups. Yahoo attempts to customize search results for its users based on their personal profiles [Yahoo Inc., 2004]. Google employs search terms keyed in by users to deliver targeted advertising (<http://www.google.com.sg/ads/>).
5. *Commoditization:* Search is a mature enough field that search companies can offer pre-packaged tools to other companies for users desiring to create their own internal search

⁵ Note that this approach is distinct from backcitation algorithms like PageRank [Brin and Page, 1998]. In backcitation, the algorithm calculates the number of webpages that cite a given webpage. ScentTrails investigates the relevance of citations on a given webpage.

engines. For example, Google provides a wide array of personal search tools such as desktop search (a tool for searching a user's personal computer), and picasa (a tool for searching personal images) (<http://www.google.com.sg/options/index.html>).

Unresolved Issues

While substantial work improved the relevance of search engine results, anecdotal evidence suggests that considerable improvement is still needed. The main limitations lie in the perspective of search engine developers with regard to: (1) data collection, and (2) information retrieval.

Data collection. The results returned by web search engines depend on the quality of web documents captured in search engine databases. However, these databases capture:

1. a small proportion of relevant web documents,
2. some inaccurate data, and
3. data not intended for public release.

Uncaptured data: Gil [2005] estimated that there are over 45 billion static web pages. Billions of these web pages are not captured in web databases. For example, the largest web database, Google, only indexes eight billion web pages [Seravalli, 2003]. Furthermore, web databases mainly capture text data. Other kinds of data such as music, images, video, and scanned documents are difficult to represent in web databases. Although searchable archives of these kinds of documents exist (e.g., on Google or AlltheWeb), these archives are kept separate for technological reasons [Olsen, 2004]. Most search engines also do not search the "deep web," e.g., dynamically generated pages [Wright, 2004].

Inaccurate data: Unlike traditional documents, documents published on the web can be easily altered. Data in search engine databases often do not capture these changes. The databases thus contain out-of-date information about web sites [Abreu, 2000, Guernsey, 2001]. A search engine may, therefore, produce results suggesting that a web document contains particular content. However, when a user retrieves the document, he or she discovers that the content is absent. Also, some web sites are "dead," and are no longer maintained actively. When users visit these web sites, they find time-sensitive data that is no longer relevant [Wright, 2004]. Furthermore, as web data is stored in a search engine database, it is transformed, sometimes detrimentally. In one case, data from the California State Board of Accountancy was unintentionally altered so that it appeared a chartered accountant had his permit revoked [Barker, 2004].

Non-public data: In some cases, search engines archive data that is sensitive to an individual or group and not intended for public release. For example, individuals' personal credit card or bank account information, medical records, or student grades are available through web searches. Even classified or secret information like warship berths are contained in search engine databases [Noguchi, 2004]. Such information is difficult to remove, because even when the compromised information is deleted from the original website, the information persists in the search engine's database.

Information retrieval. Despite improvements in search algorithm technology, many results retrieved by search algorithms are not relevant to the user. Three of the main contributors to inaccuracy are: (1) human agency, (2) mismatches, and (3) changing human intent.

- *Human agency.* Website developers want to draw users to their websites. Many developers thus engage in "ranking distortion." They actively modify their websites to achieve higher scores in a large set of search results [Manjoo, 2003, Seravalli, 2003]. One example strategy is "keyword spamming," where a webpage will contain innumerable keywords unrelated to the web page's subject matter. These words are indexed by the search engine, but hidden from the user (e.g., by being written in a small font having the same color as the background). Another is "google bombing,"

where people insert unflattering keywords into a webpage that links to a site. For example, a search for “miserable failure” on Google will return George W. Bush’s biography [Sidener, 2004].

- *Mismatches*: In some cases, limitations in the search algorithm cause it to retrieve inappropriate results. For example, a search on Google for ‘Jew’ produces mainly anti-semitic web sites.⁶ This is because ‘jew’ is a racially-charged term employed mainly by anti-semitic groups. Individuals of Jewish descent typically employ the terms ‘jewish’ or ‘judaism.’ [Google Inc., 2004].
- *Changing Human Intent*: Finally, search algorithms are oriented toward a static world view, where human behaviors and intentions do not change. Fundamental behind most search algorithms is the assumption that two users who key in identical search terms are requesting the same information. This assumption is made even in customized or personalized search engines. In these search engines, a user who keys identical search terms across two points in time is assumed to duplicate an earlier request for information [Donoghue, 2003, Koprowski, 2003, Koprowski, 2003]. This assumption is not necessarily valid. For example, a student might key ‘apache weapons’ in one session, because he or she is writing a report on American Indian tribes. In another session, the identical student is inquiring about helicopters in the American military.

MEASURES OF SUCCESS

Companies must be able to monitor the success of their web presence to justify its existence. Web presences that do not attract sufficient returns to justify their costs should be discarded in favor of more profitable ventures. The following unique considerations apply for measuring user activity on the Internet.

1. A user’s communication with a company passes through many intermediate systems. Thus, a particular message can be misrouted, or lost.
2. In some cases, the user does not interact with a company at all. Instead, information provided by the company is retrieved from another computer on the Internet (e.g., the cache of the user’s ISP, replication servers like those provided by Akamai, or caches found on intermediate routers on the Internet. Thus, while the user perceives that he or she is communicating with a company, in fact, the user is communicating with another entity altogether [Lamb, 2004].
3. A web site owner must be able to distinguish between the person communicating with the company and the machine or software used for communication. For example, some computers are in publicly accessible places such as offices or libraries. For such computers, two visits to the same site by the same machine could be indicative of separate users. Alternately, machines on the Internet can share IP addresses (e.g., dynamic IP addressing) or other forms of identification [Machlis, 2002].

Progress

The three measurement approaches described in Rose et al. [1999] (hits/server logs, cookies, and third party raters) remain important for measuring the success of an e-Commerce site. However, a number of alternate approaches evolved that both complement and compete with existing technologies. New measurement methods include:

- *Single-pixel approach*: In the single-pixel approach, a web page contains code linked to a picture (or other object) that cannot be seen by the human eye. This code is

⁶ Given that Sergey Brin, one of Google’s founders is of Jewish descent, the “bias” in the search is likely unintentional.

designed so that the image is always retrieved from the company web server [Smith, 1999]. The single-pixel approach overcomes the caching problem whereby a web-page could be retrieved from a source outside the company (e.g., the ISP cache) [Rose et al., 1999]. For example, web bugs are HTML-formatted unsolicited commercial e-mails containing single-pixel images that are given the name of the user to which the e-mail was sent. Because the image name is unique to the recipient of the e-mail, the sender guarantees that the image will not be cached elsewhere on the Internet. When the image is retrieved from the server, the sender of the e-mail knows that the recipient owns an active e-mail account [Smith, 1999].

- *Spyware*: In the spyware approach, a piece of software is surreptitiously placed on the user's machine. The software logs user activity and returns information to the spyware's owner. Spyware is the most invasive measurement approach available, but provides the most complete profile of a user's Internet activity. For example, STARR will track and disseminate every keystroke made on a computer. It is estimated that one in three machines attached to the Internet contains spyware [Kawamoto, 2004]. Because the spyware can track all of a user's activity, it can provide the spyware owner with a complete profile of a single user as the user navigates websites around the Internet.
- *Ad-centric*: The ad-centric approach combines the hits/server log, cookies, and single-pixel approaches. An independent advertising agency places images on multiple web sites. When a user visits a site, a cookie is placed on the user's machine. As the user visits other ad-laden sites, the user is identified, and additional data about the user's activities are recorded [Pintak, 2001]. For example, doubleclick.com provides advertising to multiple domains. When a user visits one domain and downloads a doubleclick ad, doubleclick.com will simultaneously deposit a cookie on that user's machine. When the user visits a second domain containing a doubleclick ad, the doubleclick server reads the cookie and cross-indexes the user's visit with the previous one.

While these three advances improve upon prior mechanisms for identification and tracking of users, they rely on favorable computer settings on the client in order to work. Client machine and browser settings can be changed to disable the use of cookies. Likewise, anti-spyware software such as Ad-aware (by Lavasoft), or Spybot Search and Destroy can prevent the use of spyware. Last, email clients can be set to disable graphics and script software. In summary, tracking and identification software is improving but not a panacea.

Unresolved Issues

Three major unresolved measurement issues are the lack of privacy, lack of standards, and inability to distinguish humans from machines.

Lack of privacy. The advent of spyware meant that advertisers can collect any information transmitted by a user surfing the Internet. Some spyware like STARR can be employed to capture all user activities. In many cases, users may not want information like usernames and passwords revealed [Kawamoto, 2004], and feel that their privacy is being invaded.

Lack of standards. While the six approaches identified (hits/server logs, cookies, third-party raters, single-pixel, spyware, and ad-centric) all attempt to measure user traffic on the Internet, they produce varying results. Even specific instantiations of the approaches produce heterogeneous findings. For example, a count based on a request for a graphic can produce a distinct figure from a count based on the graphic's transmission if the graphic was not transmitted successfully [Pintak, 2001].

Distinguishing Humans From Machines. Almost all methods for measuring Internet activity work at the machine level. Cookies, server hits, single-pixels, ad-centric, and spyware-based methods

all rely on unique identifiers stored in a computer. As users can employ different machines, and separate users can employ the same machine to visit a website, these measures do not produce completely accurate results [Lamb, 2004]. The sole exception, third-party raters, cannot be employed to gather data on specific groups; for example visitors to a particular company's website [Lamb, 2004]. Robots ("bots"), or computers programmed to "surf" the Internet (e.g., to collect information for search engines), are another problem. A robot can quickly surf through large portions of a website thereby substantially adding to a site's "hit" rate. However, as the robot is not human, it should not be counted in the statistics [Machlis, 2002].

SECURITY

Security impacts the success of e-Commerce, because one cannot easily bound security costs. A user can decide to invest \$200 to purchase a new modem and ISP connection. The user's hardware cost to connect is thus \$200. However, a virus infection on that computer can delete or damage the user's files. If the user kept (non-Internet) bank records or work files on the computer, then this loss becomes part of the user's cost. Thus, security costs can easily become the dominant cost associated with e-Commerce.

Progress

Most technological progress in security focused on innovative ways to circumvent security. As a result, malware (i.e., viruses, worms, Trojan horses),⁷ spyware, adware (i.e., integrated advertising software), and unsolicited commercial e-mail (i.e., UCE [unsolicited commercial e-mail] or spam) are pervasive in e-Commerce. The Computer Security Institute reports that more than 80 percent of companies have suffered from an infection by one or more of the over 700,000 distinct kinds of viruses [Lemos, 2003]. Spyware is endemic on Internet machines [Meyer, 2004], and 50% of all e-mail received is UCE/spam [Curry, 2003].

Malware is also increasingly sophisticated [Sturgeon, 2003]. The MyDoom/Novarg virus released in January 2004 demonstrates malware's sophistication. This virus would:

- modify the Windows registry
- search through files in the hard disk for e-mail addresses,
- send itself as an e-mail attachment to discovered e-mail addresses,
- open ports in the infected computer (i.e., backdoors), allowing MyDoom to communicate with others,
- disguise itself as an attractive file for file sharing, and make itself available to peer-to-peer networks, and
- attempt a Denial-of-Service attack against the SCO Group (a vendor of UNIX products).

Technology improvements in malware have been driven largely by synergies between creators of malware and other technology circumvention groups [Hansell, 2003, Johnson, 2003, Meyer, 2004]. Entire industries evolved that specialize in such synergies. For example, "spackers" are hackers that create technology to help spammers spread unsolicited commercial e-mail [McWilliams, 2003].

While technology to protect e-Commerce did not develop at an equal rate, some improvements occurred in this area. For example, spam filters now include content and Bayesian keyword filters that recognize spam by the frequency of certain words [Korsak, 2004]. Bayesian filters are especially useful because they self-adapt as spammers change strategies [Strickler, 2003]. This

⁷ Authors employ separate definitions for various kinds of malware. Here, a virus is malware that requires human agency. A worm is malware that does not require human agency to replicate. A Trojan horse is malware disguised as something innocuous.

tactic forced spammers to create messages containing nonsense syllables. But such messages are easily identified and deleted by spam recipients.

Counterstrike software is triggered by known hacking attempts. Such software attacks the machine from which the hacking attempt originated [Moran, 2004].

Increased attention to security issues also encouraged greater awareness of problems in the e-Commerce community [Piscitello and Kent, 2003], and led to proposals to solve the security problem. Some proposals apply existing technologies or make few modifications to the existing infrastructure. For example, one proposal suggests the addition of border routers across the Internet. The routers would authenticate the origin of a piece of information. Authentication information would be stored in unused fields in the IP protocol [Martin, 2004]. Other proposals are more invasive. For example, some suggest a radical revisiting of the SMTP protocol, especially because it contains no authentication features [Festa, 2003, Parker, 2003]. One especially radical proposal calls for reconceptualizing the Internet as a set of disparate systems. The proposal argues that homogeneity on the Internet makes it vulnerable to attack. If systems on the Internet adopted heterogeneous operating systems, protocols, and hardware, single attacks could not spread as far as they do now [Glasner, 2003, Lemos, 2004].

Mock-ups of the Internet were created to test these proposals in a safe environment. These mock-ups also allow researchers to study the effects of specific attack strategies and prepare contingencies. Examples of mock-ups include small crash-test Internets that can be used to simulate denial of service attacks [Kirby, 2003], and honeynets, i.e., false web sites designed to encourage hacking attempts. Researchers monitor honeynets to study strategies hackers employ to penetrate systems [Hoffman, 2003].

Unresolved Issues

The lack of a comprehensive security solution meant that security costs to both e-Commerce businesses and customers rose significantly. Costs mainly occur in four areas: (1) purchase of basic infrastructure, (2) knowledge cost of startup, (3) behavioral cost, and (4) ongoing maintenance cost.

- *Purchase of basic infrastructure:* It is now no longer possible to connect to the Internet or employ basic Internet tools unless one has: (1) a firewall, (2) a virus scanner, (3) a spam filter, (4) a pop-up blocker, and (5) a spyware/adware detector [Patch, 2003, Reardon, 2004]. For example, without a firewall, or updated virus scanner, and a patched version of Windows, a computer hooked to the Internet could be immediately infected by the MSBlaster worm, which would shut the computer down [Gaudin, 2003].
- *Knowledge cost of startup:* Before connecting, a user or business must know about the vulnerabilities inherent in their operating system, and browser of choice [Reardon, 2004]. Often, the knowledge required is arcane. For example, every copy of Windows Media Player version 8 contains a unique ID that can be transmitted over the Internet. The ID enables marketers to track surfing behavior across websites even if cookies are turned off. Another example is the Adobe Acrobat browser for UNIX systems which contained a flaw whereby a PDF file could help a hacker gain control of computer systems.
- *Behavioral Cost:* Particular behaviors on the Internet expose the individual or business to spam, viruses, or other problems. For example, opening a strange attachment can cause vulnerability to virus infection. Similarly, telling an online marketer to remove an e-mail address can increase the number of spam mails received because the marketer sells the address over and over again. Because new entrants to the Internet are not familiar with necessary "appropriate" behaviors, their entry to the Internet is fraught with danger.

- *Ongoing maintenance cost:* Both businesses and customers must update their systems and knowledge to protect against new threats.
 - As security flaws are made known, both businesses and customers must obtain and install patches [Berinato, 2003].
 - Anti-virus and ad-blocker programs must be updated regularly to be valuable against new malware.
 - Businesses and customers must keep abreast of latest developments, so that they can take appropriate corrective action. [Harmon, 2004].

Being out-of-date with security trends is becoming increasingly costly. For example, on July 16, 2003, a bug was discovered in MS Windows' Remote Procedure Call implementation and a patch for the bug was released. Less than a month later, on August 11, the MSBlaster worm was created to exploit the bug [Ng, 2004]. The worm victimized over 385,000 users who were unaware of the patch, or did not understand its importance [Thurrott, 2003].

STANDARDS

Standards guarantee that when consumers visit a website or perform a transaction, particular predictable events will occur. Consumers benefit, because infrastructure investments made to purchase a product from one business also facilitate transactions with another business. For example, a consumer who buys an Internet-enabled browser can visit the site of any company he or she desires. Companies benefit because they can access all consumers who subscribe to a given standard. They are also better able to exchange products and information with other companies in the same or related businesses. For example, companies subscribing to the Visa standard can access a particular method of payment.

Progress

Rose et al [1999] suggested that the "absence of well established and agreed-upon Internet standards" was an impediment to electronic commerce. Today, numerous well-established standards are available for performing disparate e-Commerce tasks. For example, Richards [2004] identifies over 160 separate standards related to XML alone. However, many of these standards have either not been adopted, or else supporters disagree about aspects of the standard [Donoghue, 2003].

Various segments of e-Commerce lack standards. For example, distinct instant messaging (IM) technologies encounter interoperability difficulties [O'Connor, 2004]. Nevertheless, in many cases, proposed standards (e.g., XMPP and SIMPLE in IM) are under development [Moore, 2003].

Unresolved Issues

These many new standards do not necessarily improve e-Commerce. The presence of so many standards suggests that many existing standards are inadequate in that new standards are welcomed to fill gaps in the market. In many situations, these new standards made e-Commerce more difficult:

Standards Hijacking. Many companies involved in the standards setting process have hidden agendas, and subvert standards to their own ends. For example, IBM announced that it held a critical patent on one of the technologies in ebXML [Berlind, 2002]. While IBM later announced that it would make the patented technology available to ebXML users royalty-free, it was nevertheless a disturbing announcement. IBM was deeply involved in ebXML standard setting, but only revealed its ownership of the patent after the standard was finalized. Companies that create *de facto* standards also often change them in unexpected ways. For example, Microsoft's Internet Explorer 6 (IE6), the de-facto standard for web browsing blocked, third-party cookies. However, because IE6 defined third-party cookies as any cookie originating from a domain

distinct from the website, it blocked cookies from companies that owned multiple domain names, rendering such companies' websites non-functional [Anonymous, October 14, 2002].

Poorly-designed standards. Many established and agreed-upon standards were designed with particular user characteristics in mind. In some cases, not all relevant user characteristics were captured. For example, Sender Policy Framework (SPF), an e-mail authentication standard, does not address legitimate mail forwarding. Some individuals prefer to use a "standardized" e-mail address such as @acm.org that is independent of the server to which their e-mail belongs. This standard allows the individual to change their e-mail provider without changing their e-mail address. As currently defined, SPF makes such mail forwarding impossible [Roberts, 2004]. Thus, individuals who desire server-independent e-mail addresses are hurt by SPF.

In other cases, user characteristics changed over time, and existing standards are inadequate for supporting e-Commerce. For example, the IPv4 Internet Protocol standard can only support 4 billion Internet addresses. While IPv4 was able to support user needs when the Internet was restricted to universities and government organizations, Internet demand today is such that the available addresses are insufficient in number to meet all users' needs [Lui, 2003].

Some standards are sufficiently imprecise that incompatible products can correctly claim to adhere to identical standards [Vizard, 2000]. As but one of many examples, two Database Management Systems (DBMS) can be ODBC compliant. However, a query that works on one DBMS can be syntactically incorrect in another- One uses the "isnull" function to identify null values in MS Access. In contrast, Oracle uses "=null." In Oracle, one lists the available tables in a database using the syntax "Select table_name from user_tables." The equivalent command in MySQL is "Show Tables."

Too many standards. In the last five years a virtual explosion of standards took place. Many standards are subsumed by others before being adopted. For example, the Document Content Description, Document Definition Markup Language, and XML-Data standards were all replaced by the XML Schema standard before being released [Richards, 2004]. Of the hundreds of XML-based standards, only a few are actually "adopted" [Donoghue, 2003]. In some cases, divergent standards conflict with each other. For example, Unicode (a standard for recognizing alphabets in human languages) and XML (a standard for message interchange) use conflicting methods for representing sheet music [Legard, 2003].

IV. COMPLEXITY OF TECHNOLOGY IMPEDIMENTS

In our survey of the practitioner literature, we discovered that all six technological impediments to e-Commerce identified in Rose et al. [1999] remain with us five years later. Furthermore, in many cases, the impediments create more difficulties today than they did five years ago. Why were the intervening five years insufficient to address these problems? We argue that the unresolved technological impediments remain in place because e-Commerce is increasingly complex.

In the early days of e-Commerce, technology was designed to address the needs of existing stakeholders. For example, early shoppers were less risk-averse (e.g., willing to use a credit card despite weak security), and more technologically knowledgeable. Such individuals were experienced with keyboards, mice, and visual display terminals that featured mainly English text. Thus, Internet technology was originally developed with few security features and relied on text as a communicative medium. However, as e-Commerce matured, additional stakeholders did not fit easily into the existing profile. For example, mainland Chinese users are now common on the Internet, and many Internet users possess few technical skills. It is increasingly difficult to adapt e-Commerce technologies to this more complex environment.

Two forms of complexity cause especial difficulties: (1) evolutionary complexity, and (2) skill complexity. Table 4 maps existing technological impediments to these two forms of complexity.

Table 4. How Existing Technological Impediments Map to Complexity

a. Download Delays

Unresolved Issue	Complexity	Origins of Impediment
Application Complexity	Evolutionary	Features are typically added to applications, decreasing their speed
Central Load Distribution	Evolutionary	Existing geographic dispersal of technology is unable to meet new user needs.
Vulnerable Infrastructure	Skill	Vulnerabilities were not conceived of during infrastructure development.
Final mile bottleneck	Evolutionary	Additional technology is layered on twisted-pair, coax, and wireless infrastructure
Cost	Evolutionary	Regulatory costs are associated with legacy system and political boundaries. Lack of players caused by natural monopoly conditions- e.g., fixed cost of building network infrastructure.

b. Interface

Unresolved Issue	Complexity	Origins of Impediment
Network externality	Evolutionary	Companies only employ interface technologies that many users can use. Users only purchase interface technologies featured on many web sites.
Disabled	Skill	Disabled users are not considered during development
Technological incompatibility	Skill	Particular technical issues are not considered during development
Human incompatibility	Skill	HCI/retrieval research findings are not considered during initial development.
Build on existing infrastructure	Evolutionary	New interface technologies must build on existing technologies.

c. Search

Unresolved Issue	Complexity	Origins of Impediment
Uncaptured data	Evolutionary	Data collection speed is slower than rate of Internet growth
Inaccurate data	Evolutionary/ Skill	Web data collection is based on static rather than dynamic perspective
Non-public data	Skill	Data security and legitimacy of restricted data are not considered
Human agency	Skill	Political implications of search engines are not considered
Mismatch	Skill	Human search characteristics are not well understood
Changing human intent	Evolutionary/ Skill	Web information retrieval is oriented toward a static rather than dynamic perspective

d. Web Metrics

Unresolved Issue	Complexity	Origins of Impediment
Lack of Privacy	Evolutionary	The Internet was not originally designed to safeguard privacy.
Lack of Standards	Evolutionary	The World Wide Web was originally conceived of as a library. Thus, the need of marketers for accurate measurement was not envisioned.
Distinguishing Humans from Machines	Evolutionary	The need to track human behavior was not envisioned as part of the World Wide Web.

e. Security

Unresolved Issue	Complexity	Origins of Impediment
Purchase of basic infrastructure	Evolutionary	Web systems are originally not designed for security. Hence, additional products must be bought to protect user/company.
Knowledge cost of startup	Skill	It is difficult to know countermeasures required to survive on Internet

Behavior cost	Skill	Users often do not take steps to protect themselves.
Ongoing maintenance cost	Evolutionary	As Internet changes, security landscape changes and this places a burden on potential victims.

f. Standards

Unresolved Issue	Complexity	Origins of Impediment
Hijacking	Skill	Organization or individuals that hijack the standard have hidden knowledge.
Poorly-designed standard	Evolutionary/ Skill	Evolving user needs are not anticipated and accounted for.
Too many standards	Evolutionary	New needs require renewed standards.

Evolutionary Complexity. It is often cheaper to adapt existing tools to meet the needs of emergent stakeholders rather than design new ones. However, as tools evolve to meet new stakeholder needs, they become so complex that unintended consequences occur.

Consider the standard e-mail transmission format (i.e., the SMTP data command) as one case. E-mail was originally conceived as a medium for transmission of text. As e-mail gained in popularity, it was asked to transmit non-text material such as Microsoft Word documents. This problem was addressed by converting non-text material into a special text format (e.g., MIME/base64 or uuencoded format), and linking that material as an attachment. Users then inquired why non-text material could not be integrated directly into an e-mail. To cater to this new requirement, e-mail programs allowed users to embed HTML code in e-mail. Non-text components of the e-mail would continue to be sent as MIME encoded attachments, but the HTML code would contain references to those components, thereby allowing the e-mail to be “displayed” correctly. Thus, users received the appearance of non-text e-mails even though the underlying representation remained text.

The integration of “attachment” technology and HTML caused a number of problems in modern e-mail systems. First, e-mail attachments are sometimes improperly delivered because the receiving server does not understand the conversion format of the sending server. For example, recipients of mail sent by some Microsoft servers would receive a file called winmail.dat instead of the correct attachment because they did not understand the Microsoft Transport Neutral Encapsulation Format (TNEF) [Microsoft Corporation, 2003]. Second, some technologies layered on e-mail were not designed with e-mail in mind, and thus resulted in unintended functionality. For instance, it is possible to embed code in HTML e-mail that identifies the recipient when the e-mail is opened (e.g., web bugs). Senders of unsolicited commercial e-mail employ such web bugs to identify e-mail accounts that are active. [Smith, 1999]. Finally, e-mails containing formatted text (e.g., bold, italics) become unreadable, because formatting controls are misprocessed.

Skill Complexity. Most modern e-Commerce tasks require individuals with multiple skills. However, because software development is always one of the necessary skills, computer programmers/developers are assigned to solve problems even when they lack other appropriate skills. Notably, many problems in commercial search engines were previously addressed by library scientists [Bates, 2002]. Nevertheless, these problems persist because the software developer often comes from a computer science rather than a library science background. Similarly, XML enthusiasts frequently are unaware of problems associated with hierarchical data management [Pascal, 2002]. This lack of knowledge did not stop them from developing an XML query language.

V. LIMITATIONS

In the years since our previous study in 1999, the Internet continued to grow rapidly. Thus any attempt to survey a broad issue like technological impediments is necessarily incomplete.

However, given that, at its heart, the Internet is a technological artifact, such a survey is nevertheless useful. To control the size of this project, we deliberately restricted its scope to:

- the six technological impediments identified in the original paper [Rose et al., 1999], and to
- practitioner articles.

OTHER TECHNOLOGICAL IMPEDIMENTS

Other technological impediments exist. This paper has alluded to at least three impediments, i.e., that: (1) the Internet is now a legacy system, (2) total cost of ownership is high, and (3) the Internet involves a North American/Anglo bias.

- *Internet as Legacy.* The modern Internet derives from numerous legacy design and implementation decisions. For example, when the developers of IP proposed classful IP addressing (i.e., IP addresses would be allocated in fixed quantities), they never envisioned the actual number of Internet users. In classful IP addressing, requests for IP addresses would be met by blocks of 16777216, 65536, or 256 IP addresses (i.e., class A, B, and C networks). As a result of classful IP addressing, numerous IP addresses were allocated to organizations that today are unused. While classful IP addressing is now replaced by Classless Inter-Domain Routing (CIDR), numerous problems associated with the original design decision live on [3COM Corporation, 2003]. For example, many organizations with unused IP addresses refuse to surrender them for reuse by other organizations.
- *Total Cost of Ownership.* Earlier, we pointed out that the cost of maintaining security on the Internet is now deemed prohibitive. However, there are other costs as well. Businesses and individuals must update their hardware, operating system, and protocols periodically to maintain access. For example, the majority of users who owned DOS/Windows 3.1 machines running SLIP based dial-ins can no longer access the Internet because few ISPs now provide SLIP-based service. Individuals (including the authors) who owned such machines have been forced to upgrade.
- *Anglo Bias.* The Internet was and continues to be designed around English language use. While standards like Unicode exist to support multiple languages, HTML tags like "<table>," and programming language commands like "if" or "switch" presuppose familiarity with the English language. However, the Internet is a global and multi-cultural phenomenon at its core, and this lingua-centricism leads to problems and misunderstandings.

In short, the six technological impediments explored in this paper do not cover all potential technological impediments to e-commerce. However, this lack of coverage does not detract from this paper's essential points, i.e., fundamental issues with Internet technology continue to impede e-commerce, and the Internet has become excessively complex.

FOCUS ON PRACTITIONER LITERATURE

In this article, we focused almost exclusively on the practitioner literature, essentially ignoring academic work. Substantial academic research is being conducted in each of the six areas. For example, most of the mainstream HCI journals publish work on the Internet and user interfaces. Similarly, multiple working groups of the Internet Engineering Task Force (IETF) are even now attempting to develop next-generation Internet protocols. It was not possible for us to review the practitioner and research literature both extensively and simultaneously.

Nevertheless, our focus on practice fills a niche in academic research. Too frequently, academics focus inward and stress our own theoretical literature to the exclusion of other problem domains. This paper brings the literature of practice into academic discourse on a pressing issue.

VI. CONCLUSION

This paper updates Rose et al. [1999] with a review of trade press articles from 1999-2004. In our review, we demonstrate that all six technological impediments identified in the original article are still relevant today. However, the nature of the impediments has changed. Specifically, in 1999, the Internet environment was much simpler, and implemented solutions were substantially more straightforward. Today, it is difficult to implement a solution that does not create at least one unintended consequence. Furthermore, developers must possess multiple skill sets to adequately address modern impediments. Unfortunately, this requisite experience in developing software is not widely prevalent.

Given that the Internet evolved to such a complex state, it is useful to ask whether solutions should be developed on the existing infrastructure, or whether the existing infrastructure should be abandoned and reconstructed with additional features in mind. There are benefits and drawbacks to both approaches. The main benefits to continuous adaptation of the existing Internet infrastructure are cost and risk. All e-Commerce ventures and users rely on the existing infrastructure, and it would be costly for these ventures and users to reinvest in a new one. Furthermore, a new infrastructure that incorporates features for resolving technological impediments would be difficult to construct, and thus prone to failure.

On the other hand, given that many of the problems identified in Rose et al. [1999] remain five years after they were reported, it is unlikely that the technological impediments identified will disappear any time soon. Thus, there may be no real resolution to these technological impediments other than abandonment of the existing Internet infrastructure.

The abandon/not abandon dilemma provides a fertile ground for research. Major strides can be made in identifying imperfect solutions to the technological impediments. Many of the technologies described here fall into that category. However, strides can be made in specifying and implementing the Internet's replacement. Indeed, the entire Internet 2 project addresses this issue [Stout, 2003].

Information systems researchers are ideally placed to facilitate research in both streams. The multidisciplinary nature of Information Systems means that IS researchers both understand the technology, and have essential non-technological skills. We can identify concerns with new adaptations to technology before they are implemented, and raise issues unaddressed by the new Internet 2 infrastructure.

Academic and scholarly research needs to expand its horizons and consider a range of challenges to the development of Internet commerce and Net-enhanced organizations. Some of these are technological challenges discussed here, all of which, incidentally, are accompanied by behavioral and organizational issues. Additional social issues identified by Rose et al. [1999] (listed as items 1 through 8 below) were explored by Straub [2004] in his book *Foundations of Net-Enhanced Organizations*, but this book only defines and delineates the problems. Social issues include:

1. Fears that consumers experience in buying or transacting business over the Web
2. Lack of e-brand awareness or significant penetration of the total market for specific e-products from companies
3. Management/cultural problems in instituting e-business practices and ideas
4. Lack of experience by firms in doing e-business (even though e-commerce is now over a decade old).
5. Organizational fear of doing business over the Internet for both B2C and B2B transactions.
6. Migrating to Internet computer-to-computer linkages from more familiar EDI
7. Lack of understanding of e-cash transactions (i.e., paying with electronic funds other than a credit or debit card, as in PayPal) on the part of consumers or organizations

IS researchers are well equipped to pursue this work by applying pertinent theories to these most pressing issues. This domain of work offers much promise, not only because solutions to these problems are needed, but also because it is fertile ground for field and empirical work. Whether IS researchers use qualitative or quantitative approaches is not the issue. The important thing is that the field meets the crisis and conducts reputable scientific studies that enlighten and inform.

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