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A Bibliometric Analysis of the Use of Technical Report Literature: Pre- and Post- Internet Distribution

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To the Graduate Council:

I am submitting herewith a dissertation written by Cynthia Gayle Manley entitled "A Bibliometric Analysis of the Use of Technical Report Literature: Pre- and Post- Internet Distribution." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of , with a major in Communication and Information.

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A Bibliometric Analysis of the Use of Technical Report Literature: Pre- and Post-Internet Distribution

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Dedication

This is dedicated to my family. Your unconditional love and confidence saw me through to the end. My parents, L.C. and Bessie Manley have encouraged and supported me in many ways during this process. Mom, it is your lifelong love of learning that inspired me to begin this journey. My siblings, Diane, Wendell, and Edgar kept me going by reminding me of Rule Number One – Never Quit!

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Abstract

Technological advances have changed the way information is accessed, retrieved, and utilized. The Internet has contributed to greater accessibility of scientific and technical information (STI), particularly in the arena of technical report literature. Technical reports, which communicate the results of research and development activities, are significant indicators of scientific trends because they often represent public and governmental interest in emerging fields of study. Prior to the widespread use of the Internet, technical reports were disseminated in print format with the use of specific, and often limited, distribution lists. However, as technical report literature found a home on the Internet, it became more accessible to the public as a discoverable resource on par with journal literature.

This study investigates the transition from the traditional paper distribution to the digital distribution of technical reports beginning in the mid-1990s. Reports produced and distributed by Oak Ridge National Laboratory (ORNL) are examined to determine trends over time and across disciplines. The scientific disciplines of chemistry and engineering are contrasted with respect to citation patterns. A quantitative analysis is used to determine whether citation patterns of technical report literature reflect the transition from print access to digital access. Publication and citation information was collected in 2009 from ISI’s Web of Science product as well as from databases maintained by the Department of Energy’s Office of Scientific and Technical Information (OSTI).

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Chapter 1

Introduction

Rapid technological advances – such as the ubiquity of the Internet and powerful computers -- have transformed the way information is accessed and disseminated. These technological changes, where information can be stored and transmitted digitally, offer the means of bypassing the printed publication process and minimizing the importance that proximity and location play.

In today's digital environment, the Internet has become a major source for dissemination and retrieval of scientific and technical information (STI) and often serves as a researcher's first introduction to a topic. Government web sites give users access to a body of digitally produced documents, such as technical reports and other grey literature, that complements the existing body of print materials and are a major source of information retrieval and dissemination. Scientific publishing on the World Wide Web makes it possible to distribute information to a global audience in a matter of minutes. Ease of access and the speed in which massive amounts of information can be made available will impact the formation of science policy and public attitudes in a more profound way than in the past.

As a result, today, communication in science is supported by a complex, interrelated system. The scientific communication system provides the framework around which scientific knowledge advances (Crawford, 1996). The process of producing, organizing and disseminating scientific information involves interactions among a variety of stakeholders, ranging from authors, to primary and secondary publishers to users. Technology affects system stakeholders by reducing costs, speeding transmission, and improving other attributes of the communication process. Information technologies and standards appear to have matured sufficiently to enable the production of more digital content, and "the production of more digital content is pushing the development of scholarly information infrastructure technologies" (Borgman, 2007, p. 31). Implementation of these standards and technologies will continue to reduce costs in creating digital documents and increase the speed with which documents can be transmitted from authors to readers causing availability of more digital content to attract more scholars and researchers towards using that content (Borgman, 2007). Research by Tenopir and King (2000) shows that three components of potential cost savings to individuals emerge when digital documents are used: the price paid; the cost of ordering, processing and storing; and the cost of looking up the documents and reading them. Each document type or form has a specific role to play as a disseminator of information and it is this role that dictates the nature of information carried, as well as the physical form and the frequency with which it is published (Nicholas & Ritchie, 1978).

1.1 Significance of the Issue

Technical reports are defined as documents that communicate the results of research and development activities that are often federally-funded. They are of interest to the research community because they represent a primary source of the intellectual production of scientists and other researchers (Swarna, 2002; McClure, 1988) and, in some cases, may have important implications for national security. The technical report literature is “an information resource that covers a wide range of subjects and is indispensable to the scientific community,” (McClure, 1988). Reports also are of long-term interest because they are often produced at taxpayer-supported research institutions and are considered a national resource. “Since technical reports constitute a sizable portion of the published information in science and technology, it is fair to raise the question as to whether research published in the reports is readily available to other researchers” (Khan, 1988). This becomes a question of interest because federal agencies would like to be able to measure the impact of the research efforts that have been carried out using public funds. McClure (1988) describes a number of barriers in the access and use of technical reports: 1) there can be a lack of awareness of the report literature; 2) a lack of understanding about how and where to obtain reports; 3) some agencies that fund research fail to require their contractors to provide a copy of completed reports to the national clearinghouses such as NTIS and OSTI; and 4) bibliographic control for technical reports is usually not included in mainstream scientific and technical databases (Cordes, 2004).

Studies (Pinelli, 1990; Khan, 1998; Bichteler, 1991) show that researchers are often unaware of the wealth of information contained in technical reports created as a result of federally-funded research. One of the ways to determine if researchers are aware of the information available in technical reports is through an examination of citation patterns in studies such as this one. Referencing other documents has the effect of either reinforcing the knowledge of prior research or making a reader aware of the existence of other relevant sources of information. Studies based on publications, such as technical reports should provide useful insights into the nature and distribution of scientific knowledge. The shift to digital distribution of documents seems inevitable (Kling & McKim, 2000; Meyer & Schroeder, 2009) because scientific communication has reached the point where it is expected that scientists and engineers will conduct more of their research activities online. This represents a fundamental change in the scholarly communication process. As digital resources become an increasingly essential component of the scholarly environment, researchers find themselves grappling with ways to measure the availability and usage of digital documents to justify the use of public funds (Lagier, 2002).

Librarians at institutions that produce technical reports have a vested interest in understanding how technical reports are used because in some instances the reports represent a substantial portion of their collections, and librarians are always trying to find ways to quantitatively describe the value of this resource to their managers. By examining how the technical report literature is used this study could provide an example of how librarians could conduct research and generate the data needed to help them describe the value of their technical report collections. It could also be used to show other stakeholders that bibliometric analysis is a viable way to generate metrics for determining the impact of the technical report literature. The study could also provide insights to the policy makers who determine how reports are to be made available and to providers of indexing and abstracting services.

1.2 Statement of Purpose

The purpose of this study was to explore the transition from the traditional paper distribution to the digital distribution of technical reports beginning in the mid-1990s. It investigated the degree of the transition from paper to digital that has occurred in these documents, and explored whether there were significant differences in use and access to these documents in two scientific disciplines – chemistry and engineering. These two disciplines were selected because application of the results of research in the chemistry and engineering disciplines tends to have an impact on society as a whole (National Research Council, 2007; Gould & Pearce, 1991). In addition, the institution examined as part of this study has groups that perform research and produce documents in these disciplines as part of its research mission.

This study examined the technical reports produced and distributed by Oak Ridge National Laboratory (ORNL), one of the multipurpose laboratories in the Department of Energy (DOE) national laboratory system which conducts research in various disciplines that support the strategic research goals of DOE. DOE is a cabinet level department in the United States government administered by the Secretary of Energy that sponsors basic and applied scientific research through its system of national laboratories. The national laboratory system was first administered by the Atomic Energy Commission, followed by the Energy Research and Development Administration, and currently the Department of Energy, and is one of the largest scientific research systems in the world (NSF 2010; DOE website 2011). The DOE provides more than 40% of the total national funding for physics, chemistry, materials science, and other areas of the physical sciences

(Jaffe, 2002; NSF 2006). This DOE laboratory was selected because the researcher has access to the institution and its technical reports. ORNL is also classified as a Federally Funded Research and Development Center (FFRDC). FFRDCs were originally established to meet the special research needs of World War II. Their primary activities usually include one or more of the following activities: basic research, applied research, development, or management of research and development (NSF 2010).

Bibliometric studies have been used in a variety of settings. In science policy contexts bibliometric indicators have been used for evaluating research and monitoring research systems. This use of bibliometric indicators in science policy is a reflection of a growing trend of demanding greater accountability in science. In this perspective evaluations and performance indicators are seen as ways in which to assure the government and the public that public funds are being well spent.

To explore these changes in distribution, a set of unobtrusive indicators, citations, were used to describe the transition. Descriptive statistics were used to identify patterns and trends that may be a result of the transition and quantitatively summarize the data set. Inferential statistics were used to test the hypotheses regarding the difference between the years 1992 and 2002 in the digital distribution and accessibility of technical reports and the patterns of how these documents are cited. This approach made the assumption that reports distributed before 1992 were mainly issued in print and those issued after 2000 were available mainly in digital format.

Citation analyses are considered a measure of research impact (Rand, 2009; Rahm & Thor, 2005) because citation implies use of the document. This study used bibliometric techniques to evaluate distribution of technical reports that are the output of both basic and applied research funded through the Department of Energy.

1.3 Research Questions

This study attempted to answer the following questions:

1. What impact has the transition from print to digital distribution had on the measurement of access and use of technical reports?
2. Is there a difference in citing patterns as a result of the increased accessibility of technical reports in digital format?
3. What are the characteristics of the documents that cite technical report literature?
4. Are chemists and engineers impacted differently by the transition of technical reports from print to digital format?
5. Is there a difference in how technical reports are cited based on subject discipline?

Scholarly information can be and is often studied through bibliographic indicators. While the number of citations usually is considered as an indicator of scientific impact, the number of publications is regarded as a quantitative measure of the research output. Citations represent a good, but not perfect measure of research performance.

Citation analysis can provide a valuable perspective on research contributions in the applied and basic sciences (Lindholm-Romantschuk, 1998). Chemistry is considered a basic research discipline that focuses on theory building and generating knowledge regarding the "properties, composition, and structure of matter and its transformation from one kind of substance to another" (Gould & Pearce, 1991). Engineering, on the other hand, is considered an applied research discipline that is geared toward problem-solving as opposed to theory building and evidenced-based research that **is** found in disciplines, such as chemistry (Gould & Pearce, 1991). These disciplines provide a potentially interesting contrast related to the research questions in this dissertation.

Information use and publication and citation practices differ among subject disciplines (Ismail, 2009; Moed, 2005; Tenopir & King, 2004; Hertzum & Pejtersen, 1999; Gould & Pearce, 1991; Garfield, 1979). Statistics compiled by the National Science Foundation (2007) provide data showing that publication patterns vary by discipline and this is a reflection of how researchers within a discipline use information resources. Other research (Narin, 2002; Schubert & Braun, 1986; Moed et al. 1985) suggests that relative indicators, not absolute citations counts should be used in cross-field comparisons of citation patterns.

By tracking the output of research and how it is used by chemists and engineers, it is possible to detect and monitor significant developments in these scientific fields. It is also possible to gain insight regarding the impact funding and national research priorities have on scientific activity. Increased knowledge of the role and impact of technical reports could assist federal policymakers in designing better delivery systems to exploit this literature (McClure, 1988) and may shed light on the amount of diffusion of information that occurs between technical reports and the journal literature.

For the purposes of this study, the format of the technical report—whether it is available in digital format or print—was one of the variables that was expected to influence the use of technical reports. In keeping with research done by Pinelli (1990), this will variable will be labeled "accessibility." The other variable of interest was the subject discipline of the citing article.

1.4 Hypotheses

The goal of this study was to provide an empirical basis for understanding the role of technical reports in the diffusion of knowledge resulting from federally funded research and development activities. This was based on the assumption that technical reports play an important part in the knowledge diffusion process and that being cited in the journal literature is a measure of usage. The dependent variable in this study is the use of technical reports as indicated by citation activity in two distinct time periods. The hypotheses of this research are as follows:

H1: Technical reports available in digital format will be cited more frequently than reports which are available in print format.

H2: Articles published in engineering journals will cite technical reports more frequently than those published in chemistry journals.

H3: There is a difference in the citation of the technical report literature based on subject discipline.

H3a: There is a difference in the citation patterns of chemists and engineers.

H3b: There is a difference in the citation patterns of chemists based on their academic or non-academic status.

H3c: There is a difference in the citation patterns of engineers based on their academic or non-academic status.

The national laboratory system plays a critical role in the nation's ability to effectively develop new technologies that can transform current technologies (BES brochure n.d.). The laboratories are responsible for supporting basic research in the natural sciences that have led to new and improved energy technologies. The laboratory system supports fundamental research in energy resources, production, conversion, and efficiency, and mitigation of the adverse impacts of energy production and use. Federally-funded activities conducted in the national laboratories are linked with US industries so that scientific discoveries can rapidly enter the marketplace. Technologies involving chemistry and engineering affect how we live in a number of ways, from growing and preparing foods, to generating energy, to manufacturing cars and semiconductors. Understanding and improving these processes are challenging and important problems.

Research done through the national laboratory system is providing the scientific foundation needed for technologies that meet the demands of both industry and society. The experiments conducted in national laboratory facilities cover a range of scientific and technological endeavors, including chemistry, physics, materials science, geology, environmental science, biology, biotechnology, and engineering science. One of the primary methods by which the results of federally supported R&D conducted within the national laboratory system are communicated within the scientific community and made accessible to the general public is the technical report. The terminology used throughout this study is defined in the following section.

1.5 Definition of Terms

Basic research is research that is aimed at providing the necessary knowledge and background for additional research that can be applied to practical problems. (Gould & Pearce, 1991)

Applied research is research that applies scientific knowledge to solving practical problems. (Gould & Pearce, 1991)

Bibliometrics is a type of research method that utilizes quantitative analysis and statistics to describe patterns of publication within a given field or body of literature. (Smith, 1981)

Big Science is a term used to describe the shift in scientific research from individual/small group projects to large-scale projects. (Price, 1963)

Citation is defined as the acknowledgement that one document receives from another. (Diodato, 1994)

Citation analysis is that area of bibliometrics that deals with the study of the relationship between cited and citing documents. (Diodato, 1994)

Electronic document standards such as SGML, HTML, XML, TIFF, and PDF enhance the ability of publishers to disseminate documents in digital format easily across varied technical platforms. (Tenopir, 2004)

Federally Funded Research and Development Centers (FFRDC) are research laboratories sponsored by federal agencies and administered by universities, industry, or other nonprofit institutions. (NSF, 2008)

Grey literature is considered to be literature which is not readily available through normal bookselling channels, and therefore difficult to identify and obtain. Technical reports are considered a subset of this category of literature. (Auger, 1994)

Impact is a measure of the influence of a publication within a research area. (Pinelli, 1990)

Little science consists of programs that tend to address limited scientific goals, providing answers to specific science problems of importance in their research field. (Price, 1963)

Open access refers to free, online access to research literature (Borgman, 2007)

Self-citation occurs when the citing document and the cited document share at least one author. (White & McCain, 1989)

Technical reports are defined as documents that convey the results of basic or applied research and support decisions based on those results. (ANSI/NISO Standard, 1995)

Millions of federal research dollars have been invested in the development of the science disseminated in technical reports. Scientists, engineers, and others depend on these reports for information that documents scientific progress. Improved access to the legacy report literature allows researchers to connect to past research relevant to their current projects, and in some cases eliminates the need to recreate the original research. Most large research libraries tend to have sizeable amounts of federally-funded technical report literature in their collections, but researchers may still consider it difficult to identify and find reports in these collections for several reasons. Science and technology indexing sources contain limited bibliographic access and control to the report literature and often more than one index must be consulted to retrieve essential information about a report (Oxnam, 2010). Technical report collections within institutions are usually available in some combination of print and microfiche and are often difficult to access without known citations and some assistance to navigate through the various collections (McClure, 1988). Library catalogs and bibliographic databases tend to include only access points at a broad series level and even fewer records for individual technical reports in their online systems, making it difficult for users to determine the availability of reports at a title level in local library collections (McClure, 1988). Until recently, the older legacy reports have not been accessible in electronic format and are usually not available via interlibrary loan.

1.6 Summary of Chapter

The impact of research is the degree to which it has been useful to other researchers (Bornmann, 2008). Information contained in technical reports provides knowledge that can stimulate new research or contribute to practical applications. Those who conduct, manage, and sustain the basic research disseminated in technical reports believe in its impact and its value and find it useful to independently assess the value of that information (BES Brochure, n.d.). Since this type of information is not well covered, its impact is not well understood (Kaplan, 2000). The study does not address issues related to reasons for citing technical reports. The findings of this study may enable librarians and other decision makers to gain a better understanding of the impact that technical reports are having within the research community.

Chapter 2

Review of Relevant Literature

The literature review describes the role of scientific communication and how different disciplines use the scientific literature. It also discusses the role technical reports play in scientific communication and puts forth a conceptual framework for studying the technical report literature.

2.1 Evolution of Scientific Communication

It is necessary to understand the evolution of scientific communication in order to appreciate how much the Internet and powerful technologies have transformed the communication process.

Prior to World War II virtually no public money was made available in the United States for scientific research. After World War II, government support for research in science intensified and grew (Goldberg, 1995). In his classic work, *Little Science, Big Science*, Price (1963) provided empirical data regarding scientific manpower, number of scientific periodicals, number of abstracts for various science fields, and citations to support his observation that the growth of science has been exponential. He described the transition from the "little science" practiced in the early days of science to the "big science" of the 1950s onwards. (He credits Alvin Weinberg with coining the term "big science" after Weinberg, then Director of Research at the Oak Ridge National Laboratory, introduced the concept of "big science" in a 1961 essay to note the fact that "many of the activities of modern science such as nuclear physics or space research require extremely elaborate equipment and staffs of large teams of professionals.") Price described the unique characteristics of "big science" as its declining growth rate, converging toward saturation; its dominance by invisible colleges; and its potential for driving far-reaching social and political change.

The concepts of big and little science are characterized by very different needs, capabilities, and difficulties. "Little science is usually represented by the lone researcher working in the laboratory on self-chosen problems. Little science programs tend to address limited scientific goals, providing answers to specific concerns of importance within a circumscribed research field. Big science, on the other hand, is often envisioned as a huge project or institute, managed by a bureaucracy that directs, the scientific paths of many researchers" (Price, 1963). Big science programs generally pursue broad sets of scientific goals that span the interests of several subfields. These goals are often backed by an influential constituency. Such programs are characterized by a sizeable personnel and physical infrastructure, complexity, and the quantities of experimental opportunities provided (National Research Council, 1994).

Big science and technology have converged in a way that has transformed the scientific communication process. Thus, "big science and powerful technology have clearly altered the way information is managed, produced and used" (Hurd, 1996). Since our society is built on the belief that access to information is critical to meaningful participation in a democratic society, these changes have impacted society at all levels. The publication process puts information into the public domain, and this includes a variety of types of information ranging from recreational to scientific.

The idea that science and scientific information could transform America gained momentum in the mid-20th century. Vannevar Bush laid the foundation for federal support of scientific research in later years in his 1945 report "Science—the endless frontier". Bush persuasively argued that scientific research was essential to advancement in three important areas of American life – defense, industry and health—and that the federal government should assume responsibility for its support (Crawford 1996). Scientific research is widely recognized as being key to economic growth and social welfare, often resulting in benefits unimagined at the time the research is initiated (NSF 2004). This makes scientific and technical knowledge "one of the most important resources in the world" (King, McDonald & Roderer, 1981).

As a result of the effort to produce new technologies to fight the Second World War, a synergy was achieved between the government and the scientific research community that established the structures, practices, and policies set in place in the post-war years which still influence the government's framework for policy making today (Boland, 2002).

Basic research "provides the means for answering a large number of important practical problems" (Price, 1963) that contribute to improving the quality of life. The full and open availability of scientific data and the open publication of results are cornerstones of basic research that U.S. law and tradition have long upheld (National Research Council, 1997). Policies of various administrations underscore the value of scientific research and its role in our society. Legislation such as the Freedom of Information Act and Title 44 of the U.S. Code provide a statutory framework that allows for the dissemination of federally generated information to the public. The public has come to believe that scientific research makes a vital contribution to society and is worthy of federal support.

The notion of access to information has been particularly significant in the scientific arena because the federal government funds a large portion of the research and development activities that occur within the United States (Knapp, 1999). According to the National Science Foundation (NSF 2004) although research and development (R&D) expenditures never have exceeded 3 percent of the U.S. gross domestic product (GDP) and the returns on investment in R&D have been difficult to measure, scholarly communities continue to study R&D expenditures as an indicator of technological change and the innovative capacity of the nation, and despite its declining share in total R&D funding, the federal Government still supports the majority of basic research in the United States.

2.2 Using Literature

The open flow of information is essential to the exchange of ideas within the scholarly community (Borgman, 2007). The scholarly literature provides formal evidence of research accomplishments. This is an essential part of the scholarly exchange and part of the creative process that can lead to new ideas (Tenopir & King, 2004). Online availability of published research has made it easier to disseminate and use that information. “Open access” is the new terminology that is used to describe literature that is digital, online, free of charge and free of most copyright restrictions (Adams, 2007).

Although more and more content is becoming available online, use of and access to much of the content still requires some form of payment.

"Digitized knowledge deserves close attention because its workings will have greater repercussions throughout the realm of research practices” (Meyer and Schroder, 2009, p. 219). Unrestricted access to documents makes them easier to read and they therefore have the potential to be cited more frequently. A growing body of research (Eysenbach, 2006; DeGroote, 2005; Malakoff, 2003) puts forth the proposition that online publication tends to increase impact. It suggests that documents freely available in digital format are cited at higher rates than those in non-digital format. This idea has some interesting implications for the technical report literature because it shows that when access is more convenient (i.e. free and digitally available), usage of documents increase. Eysenbach (2006) performed a longitudinal bibliometric study using a set of OA and non-OA articles published between June and December 2004 in PNAS: Proceedings of the National Academy of Sciences. Citation data was compared between the two groups at 3 points in time. His research found that OA articles were more immediately cited by peers than non-OA articles published in the same journal. DeGroote (2005) examined the publications of medical faculty at a large urban university to determine the impact of online journals on the citation patterns of medical faculty. She expected the use of online journals to increase while use of print journals decrease. She found that both increased. She surmised that perhaps not enough time had passed since the introduction on online journals to show a change (her study period was 1993 to 2002).

2.2.1 Differences by Discipline

The difference between scientific disciplines regarding information use has been studied frequently and various studies support the idea that chemists and engineers use information differently (Gould & Pearce, 1991; Mahe, et al., 2000; Tenopir & King, 2004). The studies have established the extent to which various communication channels (journals, reports, conversations, etc.) are used within the disciplines to obtain needed information. Research shows that chemists depend on journal literature and prefer peer-reviewed articles (Gould & Pearce, 1991). Journal articles are reported to be very important to engineers and scientists (Tenopir & King, 2004 p. 60), but they represent only a small fraction of the technical literature on most topics. Engineers spend a considerable amount time in information seeking and use (Tenopir & King, 2004, p. 63) and they prefer easily accessible information sources. Engineers tend to rely on materials like handbooks, standards, specifications and technical reports. They perform complex tasks that require complex information like that found in technical reports. (Hertzum & Pejtersen, 2000)

Reading patterns and use of information sources also vary by discipline. Scholarly journals are read more frequently than other documents (Tenopir & King, 2000). Engineers in academia use journals much more than other documents (Pinelli, 1991). Part of Pinelli's research deals with the nature of science and technology, the difference between engineers and scientists and engineers' information use behavior. In general scientists tend to use different communication channels than engineers. In this study, the term 'scientist' is used in a manner that excludes engineers so that a comparison can be made between the fields of engineering and chemistry. It is noted that in some studies the term is used in a generic manner to include all fields of science (King & Tenopir, 2001, p. 423).

There are differences in citation and publication patterns across disciplines that make cross-disciplinary comparison difficult (Ismail, 2009) and caution must be exercised in doing bibliometric comparisons without fully adjusting for these differences (Narin, 1996, p.296). By normalizing the data (Lee, 2010), differences in disciplines can be minimized. Citation densities, that is the number of references per paper, the number of times a paper is cited, and time lags all vary widely from one field to another, and one subfield to another, and sometimes even within a subfield by specialty area (Narin, 1996). Data compiled by the National Science Foundation (Appendix C) shows that more chemistry articles were published in 1992 and 2002 than engineering articles. This could lead one to assume that the chemistry discipline would receive more cites than engineering because more articles were produced.

Studies of journal use have been conducted since 1950 (King & Tenopir, 2001). For the years 1984 to 1998 scientists in several surveys reported on the amount of reading of different materials; scholarly journals were always read far more frequently than other documents (Tenopir & King, 2000) Tenopir & King (2000) make a distinction between university and non-university scientists' use of scholarly journals. There have been numerous studies and ample evidence over the years that the amount of reading and productivity of scientists are positively correlated (King & Tenopir, 2001). Engineers get most of their information from colleagues and internal reports (Hertzum, 2000). A number of studies (Tenopir & King, 2004; Gerstberger & Allen, 1968) find that the cost associated with using an information source is the most important determinant of its use and thus counter any assumption of information quality as the single criterion upon which source selection is based. Gerstberger & Allen (1968) measured the perceived cost of using an information source and found a strong relationship between accessibility and frequency of use. Chemists have more personal journal subscriptions (Noble & Coughlin 1997), read more articles (Tenopir et al., 2003) and access more journals than other scientists (Davis & Solla 2003).

The presence or absence of document forms and formats in a subject literature reveals something about the information needs and requirements of that literature (Kling & McKim, 2000). An abundance of journals suggests the literature has a high turnover of ideas, requires current information and that the results of research can be accommodated by the article-type format of the journal. The cutting edge and the historical record of chemical research are both found almost exclusively within peer-reviewed journals. Chemists are highly dependent on timely access to the most important journals in their field, which include rapid-communication and letters journals, full paper journals, and review journals. The ability to search and gather the literature quickly and efficiently is very important (Flaxbart, 2001). Flaxbart (2001) interviewed chemistry faculty to gather information about their preferred resources and opinions about the transition from print to an electronic environment. In most cases the faculty have a positive view of the transition from print to digital and describe convenience, time-saving and more titles as benefits of the digital age.

An abundance of reports and government publications are found in areas where there is considerable government involvement in the subject discipline (Nicholas & Ritchie, 1978). “Engineers tend to create less information than scientists because engineers are oriented toward the creation of technological products rather than documents” (Tenopir & King, 2004, p.72). More research conducted on differences of information creation and use between chemists and engineers and other disciplines would help an information service provider better understand and meet the information needs of those disciplines.

2.2.2 Impact of Digital Access

“The open access movement has its roots in the principles of open science that have sustained scholarship for several centuries. One of the primary motivations for open access is to make scholarly publications immediately and widely available,” (Borgman, 2007, p.101). An increasing amount of research on the effects of digital availability of information has emerged in recent years. A number of studies (Meyer & Schroeder, 2009; Craig, 2007; Lawrence, 2001; Tenopir & King, 2000; Harter, 1996) have examined the impact that online availability of journals has on scholarly communication and research. This stream of research has relevance for the study of the availability of technical reports in digital format. For example, Harter (1996) checked the references in electronic journals as a way to measure the extent to which authors were citing online sources and discussed the impact of electronic access on scholarly publication. Tenopir & King (2000) took an in-depth look at the evolution and impact of electronic journals.

Lawrence (2001) investigated the impact of the free online availability of articles by analyzing citation rates of articles in computer science and related disciplines. He found a clear correlation between the number of times an article was cited and its availability online that lead him to conclude that articles freely available online are more highly cited. Similar research by De Groote et. al (2005) looked at the impact of online journals on the citation patterns of medical faculty and found that availability of online journals may have a positive impact on the number of articles that faculty will cite.

Research has shown that scientists and engineers prefer to access their research material online (Brown, 2006). In fact, 'easy access' is top information priority (Tenopir & King, 2004). As more research is available online, readers lower the threshold of effort they are willing to expend to retrieve documents that present any barriers to access. Since Lawrence circulated his 2001 study of the impact of free online availability of computer science conference documents, the notion that freely available papers have a greater research impact has taken hold. It is now common to see the assertion that research impact is increased by open access (Meyer & Schroeder, 2009; Craig, 2007; Antelman, 2004). In addition to Lawrence small studies of the research impact of e-prints have been done for several disciplines Antelman (2004) demonstrated that open access articles have a greater research impact than non-open access articles in the disciplines of philosophy, mathematics, political science, and electrical and electronic engineering.

Free online papers are likely to reach more readers and therefore attract more citations (Malakoff 2003). There also is more indirect evidence of a link between free online availability and impact. Studies (Meyer & Schroeder, 2009; Tenopir, 2009; Brown, 2006) have shown that authors, as consumers of research information, rely heavily on browsing online journals and articles. Data showing that freely available articles in their discipline are more likely to be cited is powerful evidence of the value of open access repositories and channels (Antelman, 2004). This study's underlying assumption is that the research impact of technical reports is greater if they are freely available online than if they are not.

2.3 Role of Technical Reports in Scientific Communication

The phrase "grey literature", for many years, has been synonymous with 'technical reports.' Grey literature is considered to be "literature which is not readily available through normal bookselling channels, and therefore difficult to identify and obtain" (Auger, 1994). Examples include reports, technical notes, trade literature, preprints, conference proceedings, etc., that may be issued by government, academia, business, and industry, in both print and digital formats. Scientific grey literature comprises newsletters, reports, working papers, theses, government documents, bulletins, fact sheets, conference proceedings and other publications distributed free, available by subscription, or for sale (Auger, 1994).

Unlike the different categories of conventional literature that are subject to well-established systems of bibliographic control, grey literature usually does not conform to the standards of presentation imposed by the editors and publishers of conventional publications, nor to the rigors of a refereeing system.

Most information appearing in the technical report literature is initially prepared with a known and limited readership in mind, and often includes distribution lists as evidence of this. Also, copies often are numbered individually so they can each be accounted for. When grey literature documents are referenced in the open literature, interested would-be readers need to be able to ask for them in the correct manner.

Reports—a subset of grey literature—have been an important component of the scientific literature since the 19^{th} century and have been cited over a long period of time (Meadows 1974). Technical reports are accepted as an important primary source of information (Khan, 1988; McClure, 1988; Alberani, 1990; King & Griffiths, 1991). They are typically used to document the progress of research and development activities and for communicating scientific and technical information (STI) that is often the result of government sponsored research and cover a wide range of subject matter (McClure, 1988; Moody, 1996).

Technical reports are defined as documents that "convey the results of basic or applied research and support decisions based on those results. A report includes the ancillary information necessary for interpreting, applying, and replicating the results or techniques of an investigation. The primary purposes of such a report are to disseminate the results of scientific and technical research and to recommend action" [NISO 1995]. According to NISO, technical reports may exhibit some of the following characteristics:

1. May have a unique, issuer-supplied report number and may have a contract or grant number and an accession or acquisition number.
2. Its readership may be limited, its distribution may be limited or restricted, and its contents may include classified, proprietary, or copyrighted information.
3. It may be written for an individual or organization as a contractual requirement to recount a total research story, including full discussions of unsuccessful approaches.

4. It is not usually published or made available through commercial publishing; it is often available through a non-profit governmental entity (e.g. NTIS, GPO, etc.) [NISO 1995].

The ability of researchers to identify, acquire and utilize scientific and technical information (STI) is important to the R&D process. Evidence of the use and importance of information found in STI has typically been found in studies of scientists and researchers use of specific types of information. These studies show that engineers and scientists devote more time on average to the communication of technical information than to any other scientific activity (King & Tenopir, 2000; Pinelli, 1991). Research by King (1991) shows that technical reports are used to support specific work activities, that information found in technical reports appears to have a positive effect on the work of scientists and engineers and that technical report reading results in an average saving of $708 per reading. Garvey (1979) provides a useful discussion of the attributes of technical reports and what sets them apart from other types of publications. He notes that reports are especially important because they are distributed early in the information flow process and that because they have fewer limitations on length, style, and appendices, they contain more material than their subsequent journal counterpart (Garvey, 1979).

Technical reports are often categorized as grey literature, but in the United States there has been a long-established distribution mechanism for these documents. Technical reports are distributed through the National Technical Information Service (NTIS), the Office of Scientific and Technical Information (OSTI), the Government Printing Office (GPO), and the depository library program. NTIS is one of the largest single sources for public access to federally produced scientific and technical information (Moody, 1996). Major agencies such as the Department of Defense (DOD), the Department of Energy

(DOE), the National Aeronautics and Space Administration (NASA), and the Environmental Protection Agency (EPA) distribute their reports through NTIS. Among them, these agencies administer well over 90 percent of mission-oriented federal R&D and the technical reports resulting from this R&D.

The goal of the U.S. government is to enhance the external impact of federally funded programs in the scientific disciplines by providing a mechanism for the distribution of its research results. Legislation such as the Atomic Energy Acts of 1946 and 1954, the Energy Reorganization Act of 1974, the Department of Energy Act of 1977, and the Energy Policy Act of 2005, all call for the dissemination of scientific and technical information to the public, especially information resulting from research done under the auspices of DOE. The Energy Policy Act of 2005 states: "The Secretary, through the Office of Scientific and Technical Information shall maintain within the Department publicly available collections of scientific and technical information resulting from research, development, demonstration, and commercial applications activities supported by the Department." Since 1974, the various incarnations of OSTI have helped meet the requirements for information dissemination on behalf of the Department of Energy and predecessor agencies, the Energy Research & Development Administration (ERDA) and the Atomic Energy Commission (AEC). With the advent of the Web it became possible for OSTI to serve the DOE researcher community directly. In 1994 OSTI created the first DOE homepage, and in 1996 decisively entered the Internet era with the digitization of report literature. In 1997 the microfiche process and the printing plant at OSTI ceased production as online distribution media became the method of access to its report literature. In August 2000, OSTI added two new products to its vast collection. The GrayLIT Network provides a comprehensive portal to over 340,000 full-text technical reports from various Federal agencies.

The 1980s saw the establishment of the National Technical Information Service as an additional public outlet for all federal report information including that provided by OSTI. Public Law 64-823 charged the Secretary of Commerce with establishing a clearinghouse for the collection and dissemination of scientific and technical information to make the results of research and development more readily available to industry, business, and the general public. Today, NTIS provides public access to more than 2 million publications covering more than 350 subject areas. Although increasingly more of the current federal STI is created and disseminated in digital form, the historical collections remain almost entirely in paper or offline media products. Statistics show that about two-thirds of the titles NTIS sells in any year are more than 3 years old and over half are over 10 years old (CENDI, 2000). In the past, the typical physical format of technical reports has been paper or microfiche, but in more recent years the emphasis has shifted to a digital format since OSTI discontinued producing print and microfiche documents.

Scientific communication has reached a point where it is expected that researchers and scientists will conduct more of their research activities online because more content is available online. Accessibility is one of the key factors in determining the use of technical reports (Conkling, 1999). With the migration of information to digital format, there is a need to determine how use of information has changed with advances in technology. It has been argued that the convenience and full-text availability of government documents on the Web have had an impact on their use. Knapp's (1999) research showed that format does influence document use. Her findings provide evidence that those users accessing government documents via the Internet accessed those materials more frequently than the printed material available in the library.

Citation Analysis and the Report Literature

The literature review focused on identifying bibliometric studies that included an analysis of the publication and citation data for the technical report literature. The goal also was to find any studies that might have compared a variety of publication types or that applied bibliometric techniques to the study of technical report literature. Despite the importance of technical reports, there seems to have been few studies that "assess its importance and impact" (McClure, 1988). In the absence of a more compelling metric, citation analysis remains the best commonly available indicator of usage (Kaplan, 2000). Citation studies involving technical reports are not common (Cordes, 2004). Some studies have taken a body of journal literature in a particular field and examined the citations to report literature items contained in it (Alberani, 1990; Bourke, 1996; Khan, 1988).

The use of citation analysis in the study of technical reports or grey literature (Bichteler, 1991; Di Cesare, 2006; Cordes, 2004; Schopfel, 2004; Pelzer, 2003) has been applied in and across many disciplines. Schopfel et al. (2004) identified 14 specific fields discussed in a variety of studies. The fields of agriculture and physics are dealt with in multiple studies, while the fields of transportation, social work, environmental protection, education, astronomy, and aerospace are dealt with in one study. And, several studies in particular examined grey literature's implications for scientific communication (Cordes, 2004; Jaffe, 2002).

2.3.1 Dissemination of Report Literature

The Department of Energy (DOE) carries out its R&D missions through a system of government laboratories, universities and private industries (Decker, 1986, p. 15). It utilizes vehicles like the *Information Bridge to* provide free public access via the Internet to full-text documents and bibliographic citations of the DOE technical report literature. Documents included in this product are primarily produced from 1994 forward. Legacy (older, pre-1994) documents are added as they become available in digital format.

In 1996, the U.S. federal government mandated that the format and delivery of information provided through its agencies must change. Materials traditionally made available in multiple formats would now be made predominantly available in digital format. This decision pushed entities such as OSTI, NTIS and other distributors of government information to make the move to a digital format. This migration to a predominantly digital format forces librarians and other stakeholders to re-examine how researchers access and use government publications (Knapp, 1999).

2.3.2 Use and Impact of Report Literature

Although several research studies (Khan, 1988; McClure, 1988; Pinelli) examining government documents have been published, few studies (Moody, 1996; Knapp 1999; Lawrence, 2001) have been published since the Internet was designated as the predominant mechanism for the dissemination of U.S. Federal government information. Knapp (1999) builds on findings in research done by Peter Hernon in 1979 to provide a basis of comparison for the examination of the degree to which use of government documents have shifted in format from paper to digital. Hernon's research provided information regarding the use of government documents based on subject discipline, age of faculty and type of library. His findings suggest that the majority of usage of government documents comes from documents three years old or less.

McClure (1988) describes the paucity of information available regarding the impact of technical reports and outlines a research agenda for the study of the technical report literature. Khan (1988) found that technical reports have a low level of secondary coverage, which often makes them difficult to identify and locate. He compared the referencing patterns of technical reports with those of journal articles and found no significant difference in the total number of references between chemistry and engineering technical reports and journal articles, but found a significant difference in the total number of technical report and journal article references. Moody (1996) reviewed and analyzed the state of web access to technical report literature. She states that "the ability to publish and distribute technical reports digitally has added a new dimension to the possibilities for making technical reports widely available" (Moody, 1996, p.8). She described the major distributors of technical report literature and some of the difficulties associated with digital distribution of technical reports. Some of the difficulties include non-standard file formats that can make it difficult for researchers to access digital documents and the researchers' inability to identify and obtain relevant documents.

Until the 1940's limited numbers of technical reports were produced. Since technical reports mirror the federal research effort, increased government defense spending caused research and production of technical reports to boom, especially in the 1950s and 1960s when about 75% of the world's R&D was done in the United States. Today, that figure would be closer to 30%. In some past years, about 50% of all R&D done in the U.S. was sponsored by the federal government (Jaffe, 2002). There were about 100,000 technical reports issued each year in the 1990s. That amount varies as a function of federal funding for research and a time lag since publication usually occurs at the end of the research cycle. Research by King and his collaborators (1982) suggests that increased awareness of technical reports through use of secondary products like the Energy Database (later known as the Energy Citations database) could lead to increased use of the technical report literature.

The Energy Citations Database (ECD) contains over 2.3 million bibliographic citations for energy and energy related scientific and technical information from the Department of Energy (DOE) and its predecessor agencies, the Energy Research & Development Administration (ERDA) and the Atomic Energy Commission (AEC). The database provides access to over 259,000 electronic documents and continues to grow through regular updates. ECD includes bibliographic citations of literature in disciplines of interest to DOE such as chemistry, physics, materials, environmental science, geology, engineering, mathematics, climatology, oceanography, and computer science. It includes citations to report literature, conference papers, journal articles, books, dissertations, and patents but does not include internal use only or proprietary documents. Of the more than

2 million bibliographic records 701,759 are technical reports with 30,200 published in 1992 and 4,282 published in 2002.

2.4 Conceptual Framework

Concepts from the diffusion of innovations research provide a useful framework for examining the use and impact of the technical report literature. Rogers (1995) defines diffusion as a process through which an innovation is communicated through certain channels over time among members of a social system. Communication channels used in the diffusion process are usually categorized as mass media or interpersonal. Rogers (1995) considered mass media channels more effective in creating awareness of innovations than interpersonal channels. Mass media channels (like the internet) transmit messages using a single source to reach a large audience while interpersonal channels usually involve some sort of personal exchange between individuals. The diffusion process generally takes place within a specific time period and goes through distinct stages with awareness of the innovation as the first step of the process. This awareness is one of the crucial steps in the use of technical reports.

The rate of adoption of an innovation is the relative speed with which the innovation is adopted by members of a social system (Rogers, 1995). It is generally measured as the number of individuals who adopt the innovation in a specified period and it provides a numerical indication of the steepness of the adoption curve for the innovation. When the cumulative number of adopters is plotted over time on a frequency basis, the results show that the rate of adoption of an innovation is characterized by an s-shaped curve. Diffusion research shows that a certain percentage of potential adopters are theorized to fall into specific categories within the curve.

An innovation can be an idea, practice or object that is perceived as new by an individual (Rogers, 1995). A publication as an innovation differs somewhat from the innovations studied in traditional diffusion research because the use of a publication does not require any technical expertise from its user, although its contents might (Kortelainen, 2001). Technology has made it easy to transmit or communicate the contents of a publication, especially if it is in digital format. The diffusion of a publication lacks some obstacles typically found in the diffusion of traditional innovations (Kortelainen, 2001). In this study, adoption of the innovation is defined as the citing of the publication; and the adopter is the individual/author citing the publication.

Several studies (Kortelainen, 2001; Crane, 1972; Oromaner, 1986; Kajberg, 1996) have defined innovation as a publication or an idea represented by a publication. Research done by Crane (1972) and Kortelainen (2001) demonstrate that the theoretical framework of diffusion research can be applied in this study of the use of technical reports. In studying invisible colleges, Crane explored the diffusion of ideas through a citation analysis of articles representing those ideas. Kajberg (1996) studied the diffusion of ideas and innovations from foreign countries into the Danish library and information through citation analysis of Danish journals. Oromaner (1986) studied the diffusion of publications representing special fields in American sociology into mainstream sociology journals.

Diffusion research has generated a large body of literature about the variables related to the adoption of an innovation. Rogers (1995) lists several factors that influence the diffusion of an innovation, such as the attributes of the innovation and the information channel carrying information about the innovation as well as those of its adopters. This study explored several of the attributes of the publication based on Rogers' definitions of the attributes of an innovation. These attributes include observability, compatibility and complexity.

Observability is the degree to which an innovation can be noticed by a potential adopter (Rogers, 1995). It has been found to be positively connected with the diffusion of an innovation based upon its ease of accessibility. The results of some innovations are more easily observed and communicated than others and, because the adoption of an observable innovation can be noticed by others, it promotes awareness of the innovation. As an example, Kortelainen (2001) suggests that the impact factor of the citing journal can be used as a measurement of observability. The impact factor of the publishing journal is an important factor influencing the publication channel of scientists. This study used the citation frequency of the technical reports studied as a measure of observability.

Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of the potential adopters (Rogers, 1995). In this case, a publication as an innovation is consistent with the needs of an adopter if that adopter cites the publication. The 'compatible innovation' can pave the way for others. Compatibility of an innovation with a preceding idea can impact its adoption because past experience is often used to judge new ideas. Since the number of scientists and engineers has grown steadily over the years, so has the amount of scientific and technical information**.** This means that there is potentially a growing need for the kind of information available in technical reports. Compatibility has been found to be positively related to the rate at which an innovation is adopted.

Complexity is the degree to which an innovation is perceived as relatively difficult to understand and use (Rogers, 1995). The perceived complexity of an innovation is negatively related to its rate of adoption – the more complex the innovation is perceived to be, the less likely it is to be adopted.. Studies focusing on the relation between the publication language and the citation rate of articles have shown that articles published in English are cited more frequently than those published in other languages

The rate of adoption is the relative speed with which an innovation is adopted by members of a social system (Rogers, 1995). It is generally measured as the number of individuals who adopt a new idea in a specified period and it provides a numerical indication of the steepness of the adoption curve for an innovation. Past research has shown that when the cumulative number of adopters is plotted over time on a frequency basis, the results show that the rate of adoption of an innovation follows a normal, bell-shaped curve known as the “s-curve of adoption”.

2.5 Summary of Chapter

This study could have an impact on how librarians, particularly those located in institutions that produce technical report literature, are able to assess the use and impact of their print and digital collections. As digital resources become an increasingly essential component of libraries, librarians will find themselves grappling with ways to measure the availability, usage and usability of those resources. The importance of obtaining accurate usage data relates to the increasing need of institutions to justify the use of funds to obtain and maintain online resources. Understanding disciplinary differences in use of technical report literature has implications for effective collection development and management depends on an accurate understanding of how members of the library's community make use of technical reports in digital format.

In addition to the e-journal literature, the stream of research that discussed patents and the flow of information to the scientific community provided some insights that proved helpful in developing this study. Several other areas of research, the literature relating to corporate and annual reports in business and industry, were investigated and did not add relevant information to this topic. Also, the literature regarding e-prints was interesting, but not particularly helpful.

Chapter 3

Methodology

This research uses a bibliometric technique, citation analysis, to identify trends in citation patterns that may result from the increased accessibility of technical reports in digital format. Bibliometrics uses quantitative analysis to measure patterns of scientific publication, typically focusing on journal papers. Over the past 40 years, it has emerged as a branch of the wider field of infometrics, and has become particularly prominent as an evaluation tool over the past 20 years (Moed, 2005).

3.1 Bibliometrics

The publication of documents makes intellectual property available to the general public with the stipulation that the user credits the creator by citing his/her work (Cronin, 1984). A cited publication is one that received at least one mention in the reference list of a subsequent publication. These publications can then be categorized as types of literature. Since scientific literature is a reflection of scientific activity, the progress of science can be studied through analysis of its publications (Garfield, 1979; Noyons, 2003).

Bibliometric techniques allow for the collection and statistical analysis of numerical data about published materials. Bibliometrics is the quantitative study and analysis of bibliographic data derived from documents (Moed, 1996). It is concerned with patterns of publication and citing behavior, and it offers a powerful set of methods and measures for studying the structure and process of scientific communication (Borgman, 2002). Bibliometric researchers have assumed that scientific output as measured by publication activity is a “valid and useful representation of scientific knowledge and that studies based on publications should provide useful insights into the nature and distribution of public knowledge,” (Noyons, 2003). Bibliometric studies can be categorized as descriptive and evaluative (Hertzel, 2003). Descriptive studies describe the characteristics or features of a literature, while evaluative studies examine the relationships formed between components of a literature (Hertzel, 2003). Descriptive studies provide the basic components that are used in evaluative studies. “Although all descriptive studies are not evaluations, all the evaluative analyses are first descriptive with the evaluative taking the data one step further, providing data on the character of the literature as a whole” (Nicholas & Ritchie,1978). Citations and other bibliometric indicators are often used for monitoring scientific developments and trends in the publication activities for particular scientific disciplines, institutions and countries (Askenes, 2004).

All documents rely to a greater or lesser extent on information contained in previously published documents, creating relationships within the literature. The nature and strength of these relationships can be determined by examining the bibliographic links between the host publication and that of the cited publications. Since this study examined the relationships formed between the bibliographic components of the technical report and journal literature, it can be considered an evaluative study.

Bibliometric studies provide information about the structure of knowledge and how it is communicated. Such studies can be used to determine whether, for instance, the primary journal literature in a given field matches the needs of the workers, or whether there is a place for a new, interdisciplinary publication.

A literature is made up of a group of related documents (Nicholas, 1978) or a variety of publication types, which typically include books, journal publications, conference proceedings and technical reports. Books are authored books and monographs as well as chapters in edited books and monographs. Books do not seem to have the location and accession problems reported for technical report literature. They do however tend to share a similar low publication presence in the scientific literature reflecting their secondary role as a means of communication in the sciences (Meadows, 1974). Journal publications include research articles, reviews, notes, and letters that report original research and are published in scholarly, peer-reviewed or refereed journals and are considered the primary means of formal communication in the sciences. Conference proceedings are publications composed of papers presented at a given conference or symposium that are subsequently published together in a single publication.

Technical reports are publications of scientific work done by academic, government, or industry organizations. Reports usually have a sponsor who pays for the cost of publication and has a corresponding say in the mode of distribution. In fact, the role played by the sponsor is one of the important differences between journal articles and reports. Many reports are produced for distribution within a company or research institution, and have a restricted audience. Locating references to technical reports is challenging (Cordes, 2004). This can pose a problem for users because reports can be difficult to locate and obtain. In fact users may often have a hard time discovering that a report exists. One way to determine how reports are used is through citation analysis.

3.1.1 Citation Analysis

Citation analysis is a well-known bibliometric technique with a long history in studies of scholarly communication (Craig, 2007; Borgman, 1990) and the amount of literature about citation analysis is extensive (Hertzel, 2003). A citation is defined as the acknowledgement that one document receives from another and citation analysis is that area of bibliometrics that deals with the study of the relationship between cited and citing documents (Smith, 1981). Citation analysis relies on the assumption that formal references to other documents within a text may be meaningfully aggregated in order to describe the social and intellectual dimensions of a scientific community (White, 2001, p. 500). The technique has been used to trace intellectual influence from designated works in science and scholarship by designated authors (Zuckerman, 1987), but there has been a continuing critical appraisal of citation data as imperfect indicators of intellectual influence in science (DeBellis, 2009, Moed, 2005).

Citations can be used as approximate indicators of influence for aggregates of authors and papers (Bourke, 1996; Cordes, 2004). Major advantages of citation analysis are its high reliability and unobtrusiveness (De Bellis, 2009). Citation analysis overcomes the problem of possible non-response bias associated with surveys. Citations indicate that a document has been read or at least referenced **(Hancock, 1992)** and this can be considered a measure of use. Citations have also been used to compare the scientific impact of publications (Rahm, 2005), to monitor research systems and for evaluating research (Askenes, 2004).

The probability of being cited depends on many factors. The chance of being cited is not only related to the number of papers published in each field but also to the number of references per paper published in a given field (Price 1963). For this study a count of the number of times (*citation frequency*) the technical report literature is cited in journal articles served as an indicator of the use of the report literature. Research by Ackerman (2005) offers some potential citation measures. He describes publication frequency, citation frequency and citations per publications as ways to assess and analyze the component parts of the literature. Publication frequency or the number of items published, (P) can be used as a measure of scientific productivity, and an analysis of publication frequency (P) over time can show the shape of a literature. Citation frequency, or how often an item is cited, (C) can be used to measure the general impact or influence of a research field. Citations per publication (CPP) can be used to measure the impact of a research field normalized for the differing size of output and is calculated by dividing citation frequency (C) by publication frequency (P) or C/P.

$$\textbf{Citations per Publication (CPP)} = \frac{\textbf{Citation Frequency (C)}}{\textbf{Publication Frequency (P)}}$$

Figure 3.1 Formula for calculating average citations per publication

3.1.2 Science Citation Index Database

Science Citation Index (SCI) is a standard tool used in bibliometric studies and was used in this research project because bibliometric studies depend heavily on the existence of large quantities of bibliographic data (Nicholas & Ritchie, 1978). SCI, a database covering more than 5,800 top ranking scientific journals, was used to generate data regarding the incidence of report citations. A unique feature of SCI is that it allows cited reference searching. All references cited in the bibliography of the source documents included in the SCI database are indexed in the Cited Reference (CR) field. Every item cited in a source document is indexed regardless of type or format, including journal articles, books, reports, patents, and both authored and anonymous works (Dialog search aid for file 34/434). The CR field is made up of bibliographic elements that may be searched separately. These elements are: Cited Author, Cited Patents, Cited Work and Cited Year. The CR field is indexed as a complete phrase, retaining exact punctuation and spacing. Most, but not all, of the references in SCI are indexed and searchable by cited authors. Entries in the Cited Work (CW) field are indexed by complete phrase with a maximum length of 20 characters. The cited work field is an index of all abbreviated journal titles, book titles, and other publications, such as technical reports, that appear in cited references. This field is particularly useful for searching non-journal items and is the field that was used to perform a cited reference search for each of the technical reports published in 1992 and 2002.

Although the SCI citation indexing feature was developed primarily to provide an alternative method of information retrieval, citation analysis has also been adopted as a means of measuring the impact of individuals, journals, organizations and even countries (Cordes 2004; Pelzer 2003; Khan 1988; Vinkler 1988). Ackerman (2005) examined the Polywater literature and its publication types, which included technical reports, and analyzed them citation analysis. Cordes (2004) sought to discover if the publications issued by GESAMP, an advisory body in marine science, were used. Her study confirmed that citation analysis can successfully measure the impact of organizations that produce grey literature. “Such publications can be very influential, diffusing widely from their source”. Cited reference searching makes it possible to find articles that have cited a previously published work. Through a cited reference search, one can discover how a known idea or innovation has been confirmed, applied, improved, extended, or corrected.

The SCI documentation suggests that truncation be used in the Cited Reference (CR) field to retrieve all references that cite specific works because titles may be abbreviated or entered into the database in an inconsistent format. Citations to technical reports are entered in the SCI citation indexes in many ways. The SCI product documentation explains that report citations have the corporate author name in the cited author field, but often times this information is not included in the record. The cited work field for a report contains the title and/or report number, often fused to the organization acronym. Database errors compound the difficulty of retrieving relevant citations. Some errors occur as the cited reference strings are created and others occur in the reference lists in journal articles, where report numbers and publication dates are particularly prone to error, but any part of a citation may be incorrect (Cordes 2004).

3.2 Data Collection

Data collection was a multi-phase process. A preliminary step in the process was to identify the set of Oak Ridge National Laboratory (ORNL) technical reports to be studied. The pilot study helped to determine which databases were best suited for data collection purposes. Both the NTIS and Energy Citations databases were used to compile a listing of the technical reports published in the target years because neither database contained a complete list of the reports published. Appendix A contains a table showing the technical report output of the DOE laboratories for 1992 through 2002.

The pilot study was used to verify the accuracy of the data gathering technique and to generate a sample set of data. Citation data for the sample set of records was collected and analyzed using a five-year fixed citation window. A fundamental limitation of citation indicators in the context of research assessments is that a certain time window is necessary for such indicators to be reliable, particularly when considering smaller numbers of publications (Askenes, 2004). The five-year citation window is the year of publication plus four years. For example, for a report published in 2002 the references to the reports are counted in the five-year period from 2002 to 2006. A fixed citation widow provides an equal time period from the date of publication for each publication to receive citations. Fixed citation windows are useful for "data aggregated below the national level and not counted yearly, based on relatively small publication numbers" (Butler, 2001, p.96). The use of a fixed citation window corrects for differences in the age of publications (Campbell, 2010). A five-year window was selected because it is considered to be long-term enough to see if any distinct patterns develop in the data and the citation peak tends to occur between 3 to 5 years after publication (Peters, 1994). Also, this interval is often used in bibliometric analyses and falls neatly between a short-term (2-year) and long-term (10-year) assessment. According to Moed (2005) "a citation window of 3 to 5 years following the year of publication has proven to yield the most informative trend data." Following the identification of the citing journal articles and source journals in the cited reference search, a test database including both the reports cited by each article in the source journals and those that were not cited was constructed. Captured database elements include the source journal title and year of publication; the technical report number and its year of publication. In addition, the subject designation as defined by SCI was captured for each journal article. Collection of these additional data allowed for a more specific analysis of the data by subject discipline (Delwiche 2003). The web version of the Ulrich's Serials Directory was used to categorize the citing journals as refereed or non-refereed. This element provided another characteristic of interest regarding the use of the technical report literature.

The target years of 1992 and 2002 are representative of the time span that reflects the pre- and post-internet distribution of technical reports by the Department of Energy. In response to limitations of the SCI database, the pilot revealed that the citation count would be more accurate if a list of the institution's reports was compiled for each of the target years and a citation search performed for each report by report number instead of performing a search using the institution name and location. Locating citations to technical reports often is much more complex than finding citations to journal articles, since reports are not recorded in the citation indexes in a standard way (Cordes 2004).

The citation analysis search was conducted using the web version of the SCI database. As records were identified they were saved and imported into the study database.

3.3 Data Categories

Data obtained from documents can be systematically analyzed by developing categories for quantifying their characteristics. When used properly, it is a powerful data reduction technique. Its major benefit comes from the fact that it is a systematic, replicable technique for compressing many attributes into fewer content categories based on explicit rules of coding. Based on the type of information required for the study, the researcher must specify the characteristics to be measured, and develop rules for identifying and recording the characteristics when they appear in the item being analyzed. The categories must relate to the research purpose, and they must be exhaustive and mutually exclusive. Exhaustiveness ensures that every recording unit relevant to the study can be classified. Mutual exclusivity means that no recording unit can be included more than once within any given category**.** The data used in bibliometric studies are counts that result from the collapsing of repeated binary events – cited or not – on articles or other documents measured over some time period to a single count (Bornmann, 2008).

The small pilot study was used to test the categories. The categories were reviewed in order to refine the operational definitions and content indicators that were used to generate descriptive characteristics of technical reports and the citing journal articles. The pilot was also useful in determining the structure of the database that was used in the capture and analysis of data. Data was collected at the article level but analyzed at the journal level. The primary group of categories relating to attributes of the technical reports include (see Appendix B for Data Coding Guide):

- Cited Report – Report number or title of the document as listed in Cited References of journal article
- Report Age -- This is operationally defined as the publication date of the cited report as shown in the Energy Citations database.
- Report Format – This is operationally defined as whether the report is available in digital format or print).

Another group of categories were used to generate the descriptive characteristics of the journals and journal articles that cite the technical reports. They include:

- Source: This is operationally defined as the journal name (unique journal title)
- Subject -- This is operationally defined as the SCI subject designation assigned to the journal containing articles citing the technical reports.
- Refereed – Journal status of refereed or non-refereed as indicated in the Ulrich's Serials Directory

Categories of additional interest include: the citing institution and the location of the citing institution.

- Citing Institution -- Defined as the institution name listed in the Reprint Address field of the SCI record
- Citing Institution Location – Defined as the country name listed in the Reprint Address field of the SCI record

3.4 Data Analysis Plan

The purpose of analysis in a study is to reduce data to a form where the relationships of research problems can be tested and studied (Kerlinger, 2000). This study, with data collected using citation analysis techniques, attempts to describe the impact of technical report literature in the disciplines of chemistry and engineering and to describe the role that format plays in the use of technical report literature. The data analysis process started with the creation of frequency tables to summarize the data. Frequency tables are useful for detecting mistakes in the data (Norusis, 1999). Other tables comparing the data elements of publications within each of the disciplines were presented as needed. Inferential statistics were used to make generalizations about the data and its relationship to the hypotheses. The data was imported into the Statistical Package for Social Sciences (SPSS) software for hypothesis testing using independent samples t-tests and chi-square tests. The t-test is a commonly used method for evaluating the means in two groups whose scores are not related to each other. The test makes it possible to evaluate the difference between the means of two groups relative to the variability of their scores. Chi-square is commonly used to compare observed data with data one would expect to obtain according to the null hypothesis. The chi-square distribution determines how much deviation can occur between the observed usage patterns differing from that which might be projected. Other charts and graphs also were obtained.

3.5 Limitations

This study identified a subset of the total number of technical reports issued by one institution and examined citing of them in refereed journal articles only. Peer-reviewed journals are an essential part of scholarly publication because they help to establish a reliable body of research by reviewing and evaluating manuscripts before they are published (Weller, 2001). The peer-review process encourages authors to meet stringent standards for publication and tries to discourage scientific fraud. Peer review has been criticized (McCook, 2006; Weller, 2001) as a process that is susceptible to reviewer bias and that has the potential to suppress dissenting ideas.

In spite of the fact that Science Citation Index (SCI) is a standard resource in citation studies, one of the major limitations of using the database is that although technical reports are included in the database, they are not as well represented as journals. Therefore, in order to maximize retrieval of citations to technical reports, each search was carefully constructed to accommodate the database's structure and limitations. Although every effort was made to do a comprehensive search by using a variety of strategies, it is quite possible that relevant citations may have been missed. Identifying all the target publications produced by this institution was a complicated task because bibliographic control for the report literature is inconsistent which makes verifying ambiguous citations challenging. It should also be noted that no database can cover all relevant material and that some of the publication statistics for this study come from research done by others. Since the report publishing pattern of ORNL is similar to that of other Department of Energy sponsored research institutions (see table in Appendix A) it can be considered representative of this group of national laboratories. There may be some overlap in the research agendas of the laboratories depending on the research goals identified by the Secretary of Energy to the DOE. Oak Ridge National Laboratory (ORNL) was established in 1943 as a part of the Manhattan Project to pioneer a method for producing and separating plutonium. During the 1950s and 1960s, ORNL became an international center for the study of nuclear energy and related research in the physical and life sciences. Currently, the laboratory supports the DOE science and technology mission by performing research in areas such as: neutron science, energy, high-performance computing, systems biology, materials science at the nanoscale, and national security (DOE website, 2011).

3.6 Summary of Chapter

This section provides an overview of the methodology that was used and describes the plan for data collection and analysis (see Figure 3.2). It was hoped that using a combination of methods would create a robust set of data for analysis, and that this in turn would help provide clear answers to the research questions posed as the basis of this study.

Overview of Data Collection and Analysis

1. Established Scope of Study
1.1 Defined pre- and post-internet time frame
1.1.1 print distribution: report publication year 1992
1.1.2 digital distribution: report publication year 2002
1.2 Identified set of reports to be studied
1.2.1 Searched ORNL publications database*
*unable to use because of incompatible database
1.2.2 Searched NTIS and ECD databases
Generated a sample set of records
1.3 Conducted a pilot study
1.3.1 Verified search technique
1.3.2 Refined fields and constructed test database

2. Conducted data collection
2.1 Performed SCI search to determine incidence of
2.1.1 Compiled list of cited and uncited reports
2.2 Captured defined database elements
2.2.1 All reports: report number; publication year; times cited
2.2.2 Citing journals: journal name; publication year, subject designation; refereed status; citing institution and country

3. Conducted data analysis
3.1 Imported data into SPSS software for statistical
3.1.1 Created frequency tables to summarize data
3.1.2 Constructed other tables to compare data elements
3.2 Conducted statistical tests

Figure 3.2 offers an overview of the process used in this study to conduct data collection and analysis.

Chapter 4

Results and Data Analysis

Introduction

It required an unexpected effort to create a list of the reports produced by the institution in the years under study. At the start of this study it had been assumed that the institution's publication tracking database would be the source used to compile the information needed for this study. Unfortunately the structure of that database did not allow for the generation of a listing or count of the reports produced in 1992 and 2002. Therefore, multiple searches were performed in the NTIS database and the Energy Citations database to compile a list and a count of the institution's published reports. Table 4.1 summarizes the report output for the years studied. The table provides a total of all the reports identified for inclusion in this study broken out by the publication year of the report. It was determined that 444 (71%) technical reports were published by the institution in 1992 and 179 (29%) were published in 2002 for a total of 623 reports. A description of the data and discussion of the hypotheses follows. The citations per publication for this set of reports is 329/623 = .528. Calculating this same number (CPP) for each subject discipline creates very small numbers.

TABLE 4.1 Technical Report Output by Year Published

Year	**Number of Reports**	**Percent of Total**	**Cumulative Percent**
1992	444	71.3	71.3
2002	179	28.7	100.0
TOTAL	623	100.0	

Hypothesis 1: Technical reports available in digital format will be cited more frequently than reports which are available in print format.

The major objective of this study was to explore whether the transition from traditional paper distribution to the electronic distribution of the technical report literature affected the use of these documents. It was originally assumed that all reports produced in 1992 were published in print and those produced in 2002 were published digitally. The cited reference search was limited to the year of publication and 4 years immediately following the publication of the report to accommodate this assumption. The data shows that of the 623 reports identified for this study 141 (23%) were cited and the remaining 482 (77%) were never cited. Ninety-seven (22%) of the 444 reports published in 1992 were cited while 347 (78%) of those reports were never cited. Forty-four (25%) of the 179 reports published in 2002 were cited while the remaining 134 (75%) were never cited. The subset of cited reports were cited an average of 2.3 times compared to an average of .52 times for the total set of technical reports.

Cross tabulation tables make it possible to examine the frequencies of observations that are associated with specific categories on more than one variable. By examining these frequencies, it is possible to identify relations between sets of cross tabulated variables. A cross tabulation table (Table 4.2) of the cited and uncited reports was created to examine the relationship between these two conditions and a chi-square test was run with the results shown in Table 4.2b. The chi-square with 1 degree of freedom =.545 and p=.461 leading to the conclusion that there is no statistically significant difference in citation frequency of reports published in 1992 (print) and 2002 (digital). This in turn suggests that format did not appear to play a role in whether the reports were cited.

Table 4.2 Report Publication Year and Times Cited

			Cited		
			Yes	No	Total
Year	**1992**	Count	97	374	444
		Expected Count	100.5	343.5	444.0
		% within Year	21.8%	78.2%	100.0%
		% within Cited	68.8%	72.0%	71.3%
		% of Total	15.6%	55.7%	71.3%
	2002	Count	44	135	179
		Expected Count	40.5%	135.5	179.0
		% within Year	24.6%	75.4%	100.0%
		% within Cited	31.2%	28.0%	28.7%
		% of Total	7.1%	21.7%	28.7%
Total		Count	141	482	623
		Expected Count	141.0	482.0	623.0
		% within Year	22.6%	77.4%	100.0%
		% within Cited	100.0%	100.0%	100.0%
		% of Total	22.6%	77.4%	100.0%

This cross tabulation table contains frequency information for the publication year and whether a report was cited or not.

Table 4.2b: Chi-Square Tests – Cited/Uncited Reports by Year

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.545[a]	1	.461		
Continuity Correction[b]	.400	1	.527		
Likelihood Ratio	.538	1	.463		
Fisher's Exact Test				.461	.262
N of Valid Cases	623				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 40.51.

b. Computed only for a 2x2 table

<u>Bradford's Law</u>

The fact that the majority of reports were not cited reflects the principle of Bradford's Law which is often described as the 80/20 Rule. The rule states that 80 percent of publications are rarely cited while 20 percent are cited often. The study results reflect a Bradford distribution that can be seen in the comparison of the percentages of all cited (23%) and uncited (77%) reports. Figure 4.1 and Table 4.3 summarize the frequency distribution of the citation data and percentages of citations to each of the technical reports. In the entire set of reports only two were cited more than 10 times. The two reports, each cited 15 times, were fusion reactor progress reports.

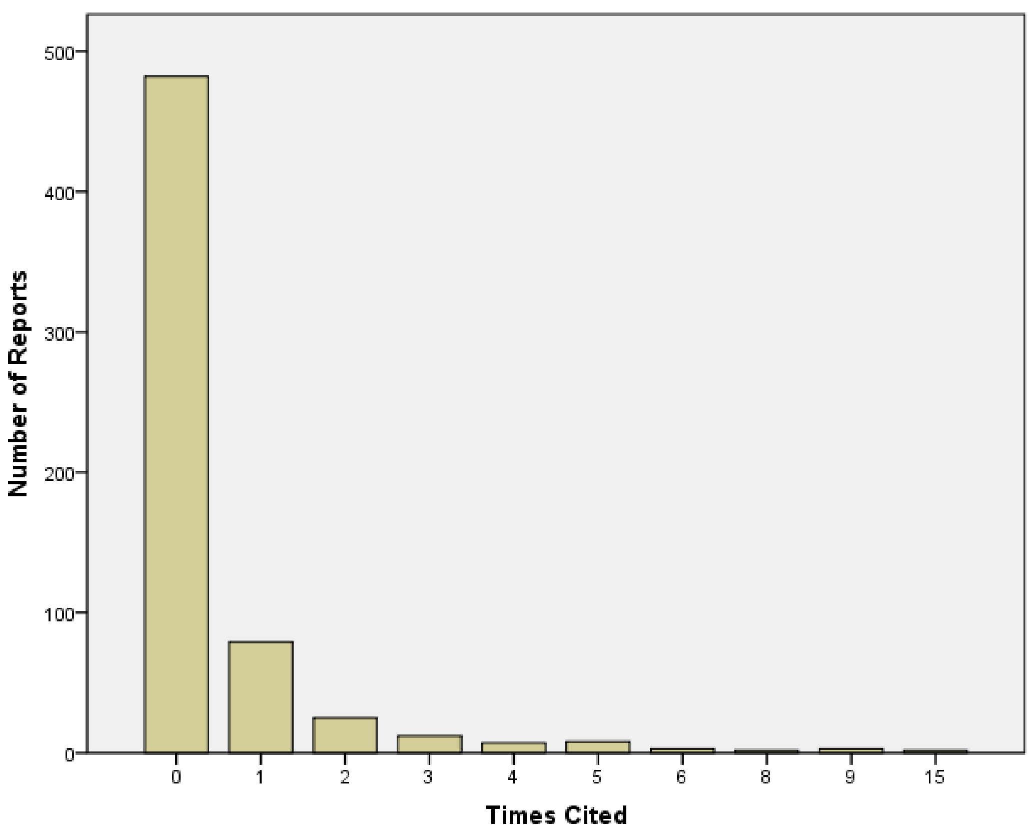

Figure 4.1: Distribution frequency of cited/uncited technical reports. This figure is an illustration of the data in Table 4.3 below.

Table 4.3 provides a tally of the total number of reports identified for this study and the frequency of citation distribution ranked from least number of times cited to the most number of times a report was cited.

Table 4.3 Total Number of Reports and Times Cited

	Times Cited	#Reports Cited	Percent	Total Cites
	0	482	77.2	0
	1	79	12.7	79
	2	25	4.0	50
	3	13	1.9	39
	4	8	1.3	32
	5	9	1.3	45
	6	3	0.5	18
	8	1	0.2	8
	9	3	0.5	27
	15	2	0.3	30
Total		623	100.0	329

Diffusion of Technical Reports

The five-year citation window provided a picture of how the reports were cited after they were published. The number of reports published in 1992 was greater than the number published in 2002 and there were more cites to the reports published in 1992 than those published in 2002. This runs counter to an expectation that the reports published in 2002 would be cited often since they were issued digitally and could be considered more accessible. Research indicates that a correlation typically exists between the publication output of authors and the number of times they are cited (Wagner-Dobler, 1997).

Figure 4.2 on the following page illustrates the citation pattern of the reports for the pre- and post-internet distribution periods. The graph shows the frequency distribution of citations per report published in 1992 and 2002 by cited year using the five-year citation window. Reports published in print (1992) hit a citation peak of 69 cites in 1994, a year sooner than those published digitally (2002) which hit a citation peak of 38 cites in 2005. There is a very noticeable drop in citations for 2002 that cannot be explained. According to research (Moed, 2005) the citation peak for a document tends to occur within 3 to 5 years of publication and this data seems to fit that trend. It was expected that the data might reflect the s-curve that usually results during the adoption of an innovation (Rogers, 1995), but it does not seem to do so. This may indicate that a citation window longer than 5 years was needed in order to see if an s-shaped curve would develop.

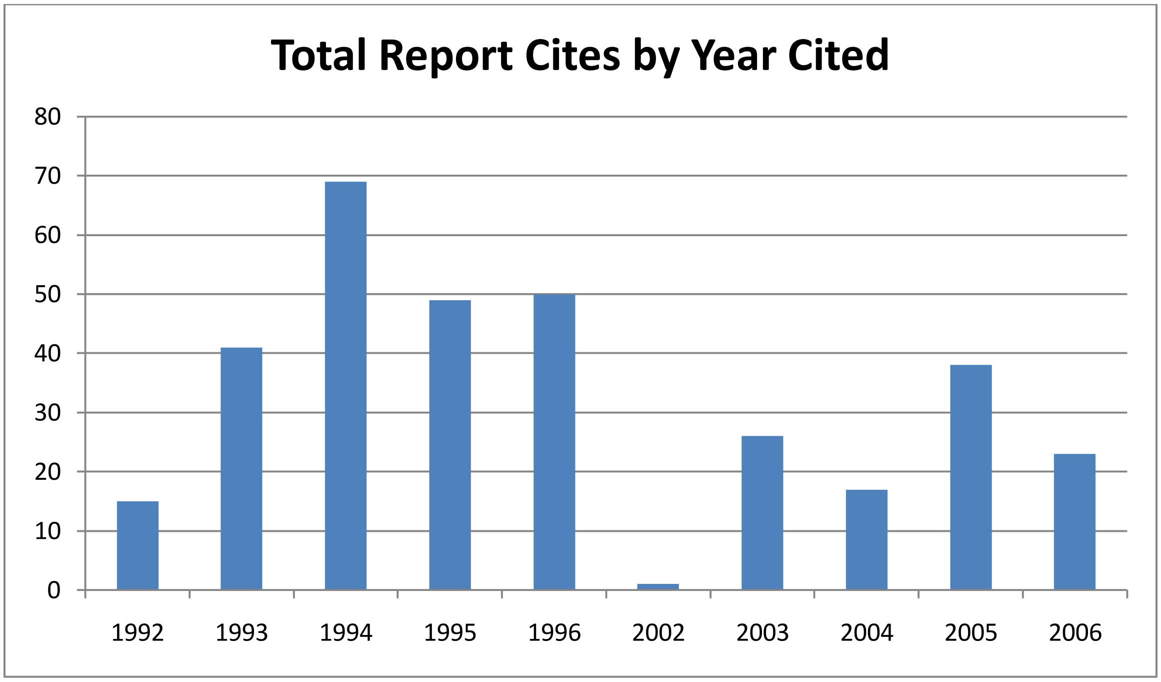

Figure 4.2 Total numbers of citations per report published in 1992 and 2002 using a 5-year fixed citation window.

Hypothesis 2: Articles published in engineering journals will cite technical reports proportionately more frequently than those published in chemistry journals.

<u>Citing Journals</u>

In the data collection process 144 unique journal titles were identified (including several conference proceedings and book series) that cited the technical reports. A table listing all the citing journal titles is included in Appendix F. The journals that cited technical reports 10 or more times were: *Journal of Nuclear Materials* (25), *Solvent Extraction and Ion Exchange*—a chemistry journal (16) and *Nuclear Technology* (11). These journals reflect subject disciplines of interest to the Department of Energy such as materials science, chemistry, and nuclear science. The only chemistry journal that cited technical reports more than 10 times was *Solvent Extraction and Ion Exchange*. None of the engineering journals cited technical reports 10 or more times. The most technical report cites for any engineering journal was nine (9) for *Environmental Science and Technology* with five (5) being the next highest number for *IEEE Transactions on Power Delivery and Transportation Research Part A*.

The study data shows that reports were cited more frequently in engineering journals than in chemistry journals and is in agreement with hypothesis 2. According to NSF data regarding article output for 1992 through 2002 (see Appendix C) more chemistry articles were published in 1992 and 2002 than engineering articles leading to an expectation that the chemistry discipline would do more citing in general that the engineering discipline. Table 4.4 summarizes the totals and percentages of chemistry and engineering journals that cited the technical reports included in this study. Of the total journals citing the technical reports 26 percent were engineering journals and 9 percent were chemistry journals. A two-tailed, independent samples t-test was run to analyze this hypothesis and produced a p=.095. This seems to suggest there is no statistically significant difference in the citing patterns of chemistry and engineering journals.

Table 4.4 Subject Categories and Citing Journals in Chemistry and Engineering

Subject Category	No. of Citing Journals (%)	Total No. Cites (%)	No. Refereed Journals
Chemistry	13 (9)	34 (10)	13
Engineering	37 (26)	73 (22)	31
Other Subjects	94 (65)	220 (68)	86
TOTAL	144	329	130

Hypothesis 3: There is a difference in the citation of the technical report literature based on subject discipline.

Hypothesis 3a: There is a difference in the citation patterns of chemists and engineers.

An important aspect of this study was to determine the impact, as measured by cites in SCI, of the technical report literature in the chemistry and engineering subject disciplines. In order to determine whether there is a difference in the citing patterns of chemists and engineers, the report citation results were sorted by the subject category of the citing journal. A macro-level approach to assigning the subject categories was adopted. The SCI categories were condensed into several broader categories based on the subject schemes used by Essential Science Indicators product (2010) and NSF in its national science indicators (2008) product. It was assumed that using the broader categories would make the data analysis more manageable. The five subject categories used by NSF are similar to DOE's strategic research areas. They include: life sciences, physics, chemistry, engineering, and mathematics (Braun, 1995).

Grouping journals into subject disciplines is a method that is often applied in bibliometric analysis (Moed 2005). The first subject term assigned to the article was used unless a subsequent term was either chemistry or engineering. If both terms occurred, the first term was selected. Each article was assigned to only one category. These subject categories are not perfect and may not be the best representation of the structure of science (Zitt, 2005) but they provide a consistent means of sorting the data. According to the SCI documentation, the subject category field reflects the subject category of a journal, not the subject of the article. The subject area of the journal represents a higher level in the knowledge hierarchy.

The citing journals were assigned into 29 SCI subject categories. The complete list of the SCI subject categories of the citing journals are in Appendix D. Appendix D shows that the SCI subject categories containing journals citing the technical report literature more than 10 times were engineering (61); materials science (43); nuclear science and technology (36); chemistry (22); physics (22); environmental sciences (25); computer science (11); and metrology and atmospheric sciences (11). There were no social science categories which aligns with the laboratory's research areas.

The SCI subject categories were collapsed into eight broader categories based on several subject classification schemes (NSF, ESI, SCI, Moed, 2005). They were grouped into chemistry, engineering, physics, computer science and mathematics, environmental science, materials science, nuclear science and other sciences. Table 4.5 lists these subject categories ranked in order of those citing the technical reports most frequently. SCI subject categories with less than one entry were grouped with other related subject categories.

Table 4.5 Frequency Distribution of Citations by Subject Category

Subject Category	**Number of Cites**	**Percent of Total**
Engineering	73	22
Environmental Science	61	19
Materials Science	46	14
Nuclear Science	39	12
Chemistry	34	10
Physics	33	10
Other Sciences	27	8
Computer Science and Mathematics	16	5
Total	**329**	**100**

The cross tabulation table below (Table 4.5a) shows report citations by subject broken out by the citing years. The chi-square value is 140.209 with 63 degrees of freedom and p=.000 indicating that there is a statistically significant difference in the citing patterns of the subject disciplines and shows support for both hypothesis 3 and hypothesis 3a. Overall, citing in earlier years (1992-96), indicating use of print format reports, tended to occur more frequently than in later years (2002-06) for most subject disciplines. Disciplines citing the print reports included computer science and mathematics, engineering, environmental sciences, materials science, nuclear science and physics. Chemists and the disciplines categorized as 'other' seemed to cite the digital reports more than any of the other subject disciplines.

Table 4.5a Total Report Citations by Subject and Each Citing Year

		Subject2								
		Chemistry	Computer Science and Mathematics	Engineering	Environmental Sciences	Materials Science	Nuclear Science & Technology	Other	Physics	Total
CitedYR	1992	0	1	2	3	7	0	0	2	15
	1993	0	5	13	3	8	7	0	5	41
	1994	4	4	18	7	19	8	2	7	69
	1995	2	3	10	9	6	10	3	6	49
	1996	4	2	13	16	4	1	7	3	50
	2002	0	0	0	0	0	0	0	1	1
	2003	6	0	3	8	1	2	0	6	26
	2004	5	1	2	3	0	3	3	0	17
	2005	8	0	8	8	1	5	7	1	38
	2006	5	0	4	4	0	3	5	2	23
Total		34	16	73	61	46	39	27	33	329

Table 4.5b Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	140.209[a]	63	.000
Likelihood Ratio	151.507	63	.000
N of Valid Cases	329		

a. 54 cells (67.5%) have expected count less than 5. The minimum expected count is .05.

Table 4.6a shows the report citation frequency for the chemistry and engineering disciplines by publication year. This is the number of cites to the technical reports, not the number of reports. To determine whether there was a difference in citing patterns by subject discipline, a chi-square statistical test was deemed appropriate. A cross tabulation (Table 4.6a) was run to get totals for the report citation frequency distribution by subject and report publication year. Examining the chi-square table (Table 4.6b) shows the chi-square value is 54.802 with 7 degrees of freedom and p=0.000 indicating a statistically significant difference in citing of reports by format and subject discipline.

Table 4.6a: Total Cited Reports by Subject Discipline and Year

		Subject2								
		Chemistry	Computer Science and Mathematics	Engineering	Environmental Sciences	Materials Science	Nuclear Science & Technology	Other	Physics	Total
PubYR	1992	10	15	56	38	44	26	12	23	224
	2002	24	1	17	23	2	13	15	10	105
Total		34	16	73	61	46	39	27	33	329

Table 4.6b: Chi-Square Tests for Cites by Subject and Year

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	54.802[a]	7	.000
Likelihood Ratio	59.623	7	.000
N of Valid Cases	329		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.11.

H3b: There is a difference in the citation patterns of chemists based on their academic or non-academic status.

H3c: There is a difference in the citation patterns of engineers based on their academic or non-academic status.

Determining the link between author affiliation and subject area was another step in the data analysis process. The author affiliation information was taken from the Reprint Address field in the SCI record. Table 4.7 summarizes the data showing that authors affiliated with non-university institutions cited the technical report literature more frequently (65%) than authors affiliated with university institutions (35%). The report literature was cited by the authors from 59 university institutions and 62 non-university institutions. Studies by Pinelli (1990), Khan (1998) and others have shown that researchers are often unaware of information contained in technical reports and can lack understanding of how to obtain reports that would be useful in their research.

Table 4.7 Frequency of Cites to Technical Reports by Institution Type

Institution	Number of Institutions	Frequency of Cites	Percent	Cumulative Percent
University	59	114	34.7	34.7
Non-University	62	214	65	99.7
Unknown	1	1	.3	100
Total	122	329	100	

The university citing the technical reports most often was the University of Tennessee which is located within 30 miles of the ORNL facility. The non-university institutions include the national laboratories, research institutes and commercial entities. The national laboratories cited the report literature 129 times with authors at ORNL citing the report literature most often with 101 cites. Self-citation is an expected result in any citation study (White & McCain, 1989). In a citation study of an organization, citation of work published by others in the same organization may be noted (Cordes, 2004). Researchers at national laboratories, like ORNL, and other similar institutions are likely to be more aware of the existence of technical reports because they required to produce reports are part of their obligation to the sponsoring agency.

Thirty-nine of the university institutions were located in the Unites States and the remaining 20 in other countries. Forty of the non-university institutions were located in the United States and 18 were located in other countries. Researchers in non-university settings tend to work for mission or product oriented organizations (Tenopir and King, 2004) and may use the technical report literature more frequently because reports often contain information that can help solve technical problems.

Table 4.8 shows all the subject categories broken out by university and non-university institutions. In all subject areas, the non-university institutions cited the technical report literature more frequently than university institutions. Non-university chemists and engineers cited the technical literature more frequently than their university counterparts. Chemists in university institutions cited the technical report literature 10 times and those in non-university institutions 24 times. Engineers in non-university institutions cited the technical report literature 44 times compared to 30 times by those in university institutions. “Scientists in government establishments nearly always use reports more than university scientists do” (Meadows, 1974, p.117).

A cross tabulation table (Table 4.8a) of the institution type by subject and year was created to examine the relationship between the academic and non-academic status of researchers in the subject disciplines covered in this study and a chi-square test was run with the results shown in Table 4.8b. The chi-square value for non-university institutions is 127.492 with 63df and p=.000 leading to the conclusion that the citing pattern differentiating university and non-university institutions is statistically significant and shows support for both hypothesis 3b and hypothesis 3c. A t-test also showed a statistically significant difference (p=.0267) in the citing patterns of university and non-university institutions. The chi-square value for university institutions is 84.858 with 56 df and p=.008. A t-test was run for hypothesis 3b and 3c to see if there was a difference in the citing patterns of chemists and engineers based on their academic status. The t-tests showed no statistically significant difference in citing patterns based on academic affiliation for chemists and engineers (H3b, p =.1379 and H3c, p =.5379).

Table 4.8 Frequency of Citations by Institution Type and Subject Category

Institution	SUBJECT CATEGORIES								
	Chem	**Eng**	**Env**	**Mater**	**Nuc**	**Phys**	**Comput**	**Oth**	**Total**
University	10	30	20	13	15	7	8	11	114
Non-University	24	44	39	33	24	26	8	16	214
Other	0	1	0	0	0	0	0	0	1
Total	34	75	59	46	39	33	16	27	329

Table 4.8a: Subject by Institution Type and Citing Year

Count

InsType			Subject2								Total
			Chemistry	Computer Science and Mathematics	Engineering	Environmental Sciences	Materials Science	Nuclear Science & Technology	Other	Physics	
Univeristy	CitedYR	1992	0	0	1	0	2	0	0	1	4
		1993	0	3	4	1	3	3	0	2	16
		1994	2	2	8	2	4	2	2	0	22
		1995	1	2	1	3	2	6	1	3	19
		1996	1	1	6	4	1	0	0	0	13
		2003	0	0	2	3	0	0	0	1	6
		2004	0	0	0	3	0	0	3	0	6
		2005	4	0	5	1	1	3	4	0	18
		2006	2	0	3	3	0	1	1	0	10
	Total		10	8	30	20	13	15	11	7	114
NonUniversity	CitedYR	1992	0	1	1	3	5	0	0	1	11
		1993	0	2	9	2	5	4	0	3	25
		1994	2	2	10	5	15	6	0	7	47
		1995	1	1	9	6	4	4	2	3	30
		1996	3	1	7	12	3	1	7	3	37
		2002	0	0	0	0	0	0	0	1	1
		2003	6	0	1	5	1	2	0	5	20
		2004	5	1	2	0	0	3	0	0	11
		2005	4	0	3	7	0	2	3	1	20
		2006	3	0	1	1	0	2	4	2	13
	Total		24	8	43	41	33	24	16	26	215

Chi-Square Tests

InsType		Value	df	Asymp. Sig. (2-sided)
Univeristy	Pearson Chi-Square	84.858[a]	56	.008
	Likelihood Ratio	92.025	56	.002
	N of Valid Cases	114		
NonUniversity	Pearson Chi-Square	127.492[b]	63	.000
	Likelihood Ratio	133.295	63	.000
	N of Valid Cases	215		

a. 70 cells (97.2%) have expected count less than 5. The minimum expected count is .25.

b. 68 cells (85.0%) have expected count less than 5. The minimum expected count is .04.

Citation Frequency by Country

It was relatively straightforward to gather information about the citing institution in spite of the fact that the information in the corporate address field does not always directly correspond to the author information, making it difficult to be certain which author is affiliated with the institution listed in the corporate address field. It was possible to have a greater certainty about the author's institutional affiliation and location by using information from the Reprint Address field. The SCI record lists the reprint author with the associated reprint address, so it was easier to be certain about the accuracy of the link between the author, institution and location.

Country of origin data collected from the Reprint Address field showed (Table 4.9) that institutions in the United States accounted for approximately 83 percent of all the references to technical reports. There was one record with missing data so the institution and country designation could not be determined.

Table 4.9 Number of Report Cites by Country: US/Non-US

	Frequency of Cites	Percent	Cumulative Percent
US	273	83.0	83.0
Non-US	55	16.7	99.7
Other	1	.3	100.0
Total	**329**	**100.0**	

A more detailed breakdown in Table 4.10 shows there were 122 citing institutions located in the United States and 18 other countries. The technical report literature was cited most frequently by institutions in the United States with 273 citations followed by Japan (12), Canada (10), Germany (5), Italy and the Netherlands (4), France (3), Indonesia (2) and Spain (2), and 10 countries citing the report literature once (1).

Table 4.10 Total Number of Cites of Technical Reports by Country

Country	No. Institutions	No. Cites
United States	83	273
Japan	5	12
Canada	8	10
France	5	6
Germany	4	5
Netherlands	2	4
Italy	3	4
Spain	2	2
Indonesia	1	2
Austria	1	1
Belgium	1	1
China	1	1
Ireland	1	1
Israel	1	1
Pakistan	1	1
Portugal	1	1
Russia	1	1
Switzerland	1	1
United Kingdom	1	1
Unknown (missing data)	1	1
TOTAL	**122**	**329**

The cross tabulation Table 4.10a shows citing of reports by country designated as US or non-US. In this table the ‘unknown’ institution is included in the US total for convenience. US institutions may have cited the report literature more often because institutions in the US tended to be the producers of the reports and users were more likely to be aware of their existence and to have the ability to obtain the reports for use. Results from the chi-square test are shown in Table 4.10b. The chi-square value for US institutions citing the report literature is 129.133 with 63 df and p=.000 indicates that the difference in citing patterns of US institutions is statistically significant and that of non-US institutions is not.

Table 4.10a Total Number of Cited Reports by Subject, Country and Year

CitedYR * Subject2 * Country Crosstabulation

Count

Country			Subject2								Total
			Chemistry	Computer Science and Mathematics	Engineering	Environmental Sciences	Materials Science	Nuclear Science & Technology	Other	Physics	
USA	CitedYR	1992	0	1	1	3	5	0	0	2	12
		1993	0	4	13	3	6	7	0	5	38
		1994	4	3	14	7	15	8	2	6	59
		1995	2	3	9	6	4	8	2	5	39
		1996	2	1	13	12	2	1	7	3	41
		2002	0	0	0	0	0	0	0	1	1
		2003	6	0	3	7	1	2	0	6	25
		2004	5	1	2	2	0	3	1	0	14
		2005	5	0	6	8	1	5	5	1	31
		2006	3	0	2	2	0	1	5	1	14
	Total		27	13	63	50	34	35	22	30	274
NonUSA	CitedYR	1992	0	0	1	0	2	0	0	0	3
		1993	0	1	0	0	2	0	0	0	3
		1994	0	1	4	0	4	0	0	1	10
		1995	0	0	1	3	2	2	1	1	10
		1996	2	1	0	4	2	0	0	0	9
		2003	0	0	0	1	0	0	0	0	1
		2004	0	0	0	1	0	0	2	0	3
		2005	3	0	2	0	0	0	2	0	7
		2006	2	0	2	2	0	2	0	1	9
	Total		7	3	10	11	12	4	5	3	55

Table 4.10b **Chi-Square Tests**

Country		Value	df	Asymp. Sig. (2-sided)
USA	Pearson Chi-Square	129.133[a]	63	.000
	Likelihood Ratio	130.945	63	.000
	N of Valid Cases	274		
NonUSA	Pearson Chi-Square	73.909[b]	56	.055
	Likelihood Ratio	79.029	56	.023
	N of Valid Cases	55		

a. 63 cells (78.8%) have expected count less than 5. The minimum expected count is .05.

b. 72 cells (100.0%) have expected count less than 5. The minimum expected count is .05.

Refereed Status of Citing Journals

Coding of the refereed status of the journals was straightforward. The web version of the Ulrich's Serials Directory contained an icon that made the journal refereed status immediately obvious. All the chemistry journals that cited the technical report literature were refereed journals. Thirty-one of the 37 engineering journals that cited the technical reports were refereed and the remaining six (6) were non-refereed titles. Appendix E lists all the citing journals and their refereed status. Publication in refereed titles tends to be more highly valued than publication in non-refereed titles (Moed, 2005) because refereed status plays a role in how researchers are evaluated by their institutions. Both university and non-university authors exhibit a preference for publishing in refereed journals because it lends visibility and credibility to their work. Refereed status provides an indication that the published research has been critically examined by other knowledgeable researchers within the field and should therefore contain reliable information, be error free and of potentially high quality. Non-refereed materials may not be scrutinized as rigorously as refereed materials, but they may still be considered scholarly publications.

5

Conclusions and Recommendations

As stated in the first chapter, the main purpose of this study was to explore whether the transition from traditional paper to digital distribution has affected how technical reports are used (i.e., cited). The study sought to specifically answer whether there was a difference in citing patterns as a result of the availability of technical reports in digital format. It also sought to identify the characteristics of the literature that cited the technical reports and investigated how technical reports were used in two specific subject disciplines: chemistry and engineering. The study findings provided insight into how use of the technical report literature has been impacted by format changes. Each hypothesis was tested for statistical significance and the implications of the results as they relate to the five research questions and the associated hypotheses are described in the discussion that follows.

Discussion

Impact of Transition from Print to Digital

In general, the transition from print to digital distribution of technical reports has had an obvious effect on the physical availability and convenience of access to the report literature. Technical reports issued in print format often had a limited distribution making them potentially difficult to obtain even when users were aware of their existence. Now that published reports are issued only in digital format, librarians, publishers, policy makers and funding agencies assume that it is much easier for researchers to identify and obtain technical reports because they can be located quickly through keyword searches in search engines, and if stored on publicly accessible servers, digital versions can be downloaded immediately for use or read online.

This study found no statistically significant difference in citations to reports in digital format versus print format. Hypothesis 1 is not supported because the data provide no clear indication that format played any part in how the technical reports were cited. Given that documents available in digital format are easier to locate and use, it was expected that reports available digitally would be used (i.e., cited) more often than those in print. It seems counter-intuitive that the digital reports were cited less frequently than the print reports, but other factors may have been at play. After some reflection, it became evident that the time frame, 2002, may have been a little early in the digital distribution process for users to be confidently aware that technical reports were accessible online and the fact that fewer reports were published in 2002 meant the possibility of those reports being cited was more limited than for those published in 1992.

It was noted that more reports were produced in 1992 than in 2002. The publication years of 1992 and 2002 were used as surrogates to indicate report format. Reports issued in 1992 were assumed to be print and those in 2002 were assumed to be digital. It seems likely that this difference in the level of output may have been the result of changes in the procedures for distributing and depositing reports with NTIS and OSTI when the reports began being issued as digital documents. This may just be a reflection of how researchers use digital documents differently (Kurtz, 2005). In fact, Meadows (1974) suggests that reports tend to be read more frequently than they are cited. Conversations with the laboratory librarians and records managers suggested that before the transition to issuing reports in digital format, the laboratory's technical reports had an explicitly stated distribution scheme and procedure that was no longer used after the institution began producing its reports in digital format only. A copy of each print report was automatically deposited with NTIS and OSTI and entered into the respective databases, but the distribution channels for digital reports do not seem to have followed this process. An investigation of the DOE published guidelines for handling STI, which includes the distribution of technical reports, did not reveal any changes in reporting requirements that might have impacted report output in 2002. The guidelines explicitly describe requirements for depositing the digital reports with OSTI bud did not mention distribution to NTIS.

Both the NSF data (see Appendix C) and the study data seem to reflect a similar decline in journal article production and technical report production between 1992 and 2002 causing one to speculate that a variety of factors may have been influencing scientific and scholarly output. This is notable because if fewer articles and reports were published, there were potentially fewer opportunities for the technical report literature to be cited. These results suggest that either some other method of study may provide a clearer picture of usage based on format or a larger dataset may be needed. Examining the reports from this dataset in a longer citation window may shed some light on citation patterns based on format.

Differences in Citing Patterns for Chemistry and Engineering

The hypothesis relating to the citing pattern of the journal literature by subject discipline seems to be borne out by the data. Analysis of journal citing patterns might have been more visible with a larger dataset. The number of journals, particularly in chemistry, that cited the technical reports was fairly small.

The hypotheses relating to the differences in citing by subject (hypothesis 3, 3a, 3b, and 3c) were supported by the data. The statistical tests showed that citing by subject discipline did seem to be affected by format. Specifically, chemists and engineers did appear to cite the report literature differently.

Characteristics of Citing Literature

Technical reports were cited more often by researchers in non-university settings than their counterparts in university settings. This may be the case because the kind of information that is typically found in reports may be more relevant to applied research that is focused on problem solving. Although there is evidence of collaboration with universities and institutions in other countries, the majority of citations to reports came from institutions within the United States.

The top five subject disciplines that cited the report literature were engineering, environmental science, materials science, nuclear science and chemistry. Report use in these disciplines could be a reflection of the level of government funding that supports research at both the university and non-university institutions and in particular, it may just reflect the research mission and activities of ORNL.

The majority of citing journals were refereed titles. This is interesting to note because according to Opthof (2002) the peer review process has the potential to successfully identify documents that have a greater chance to be cited in the future. Since reports are being cited in refereed titles they potentially have a greater visibility than they might otherwise have had.

Diffusion Concepts

Concepts from the diffusion of innovations arena provided the framework for this study. The study viewed technical reports as innovations that are diffused when they are cited within the scientific and scholarly community. Cited reports have the characteristics of observability and compatibility. The citation frequency of the technical reports is considered a measure of observability. That the report is cited is evidence of compatibility – the author found something of use within the document and cited it. Online availability of technical reports makes it easier to disseminate the information in them more rapidly and reduces the complexity of use. Because the digital reports are made available in a standard format (pdf) that can be used by anyone this ease of access reflects the lack of complexity that is positively associated the adoption of an innovation. Research by Eason and his colleagues (2000) that examined a twenty-two month transaction log for an electronic journal, found that ease of use as perceived by the user was one of the most significant factors affecting use of electronic journals.

The adoption of an innovation usually begins slowly at first and then begins to occur more rapidly until the population becomes saturated and the adoption rate slows again (Meadows, 1974). An effort was made to determine whether the citing pattern of each subject discipline in the study followed the s-curve of adoption for 1992 through 2006. The data seems inconclusive because there is a gap in citing for 2002 that makes it difficult to determine whether an s-curve occurs. This might be an instance where the years between 1996 and 2002 would need to be included in order to see if the s-curve reflecting adoption exists. The report citation results as charted in Figure 4.2 did not seem to fit the adoption curve. This might indicate that it would have been better to identify a set of highly cited reports and perform a citation analysis with a longer citation window to see if the citing activity would better match the adoption curve.

Citations provide a definite node in tracing the influence and impact of one research on another (Khan, 1988). How frequently the publications of an institution have been cited says little on its own. Bibliometric analyses may provide useful information to policy makers regarding the impact research funding can have on scholarly activity. Citation studies involving the technical report literature are uncommon. This study revealed that very few of the total number of technical reports were widely used.

Bibliometric studies provide stable measures of citation impact but this type of data cannot tell what factors affected the identification and selection of technical reports for use. It would be interesting to try to determine how users found the cited technical reports and how often the digital versions of the reports were accessed. This approach would require technical assistance from the IT department to gain access to the laboratory’s server logs in order to capture transactional data for the digital documents and might violate security or privacy policies.

Implications for Stakeholders

This study provides information that can be used by a variety of stakeholders who are impacted by the access to and use of the technical report literature. Some of the stakeholders in access and use of technical reports include librarians, publishers, policy makers, funding agencies, and researchers. Librarians who maintain technical report collections play an important role in facilitating user access to those reports in all the available formats. They have a vested interest in providing access to such collections and understanding how those collections are used. Being able to quantify collection usage enables them to better describe the value of this library resource to their managers. This study can serve as a model for collecting usage data that can inform strategic decisions regarding the effectiveness of library collections and services to users. This study shows that other, complementary, metrics such as library loan data and information requests (Meadows, 1974) need to be developed to help analyze report usage in a more systematic way. This researcher believes that it would be ideal to develop statistics similar to those used by NSF in its science indicators product. Such a product could be a very useful tool for the national laboratory librarians or any other library that has a collection of technical reports. This study also encourages finding ways to use new citation databases to analyze report usage.

In providing bibliographic access to the report literature, publishers play a critical role in creating systems that help users identify, locate and obtain technical reports. If databases do not index the report literature that is one less way for users to find the information they need. Issues of barriers to the access and use of technical reports continue to be of interest to researchers and librarians because problems of access to use technical reports can limit their usefulness (McClure, 1988). “Unfortunately, lack of access has caused many users to be unaware of material which would satisfy their information needs,” (Bichteler, 1991, p.40). Interaction with librarians can help publishers keep databases updated with the most accurate information regarding technical reports. Analysis of the use of technical reports might help forge an added dimension to the relationship between librarians and the database publishers who index (or choose not to) report literature. A systematic collection of usage data would provide a way to begin a dialog regarding ways to enhance access to technical report through bibliographic control methods and indexing techniques.

The inherent characteristics of technical reports can create barriers in access and use. Some technical reports are classified or are placed on restricted distribution lists and cannot be accessed without appropriate clearance codes. Sometimes contractors may fail to provide a copy of the sponsor-required reports to a national clearinghouse such as NTIS or they may choose not to include “really useful or important findings” because they want to maintain proprietary control over the information. Bibliographic control over technical reports is limited because relatively few reports tend to be included in standard scientific and technological databases. Physical accessibility can lead to the perception that information is readily available and convenient to use. Such perceived accessibility increases the likelihood that documents will be used in the future. Physical influences and constraints on access can alter the complex relations of power in technological development, information flow and how much one can have access to information.

Policy makers are responsible for funding and publication dissemination decisions and the guidelines they establish can determine who gets access to information published in technical reports. Policy makers and funding agencies strive to foster the best possible research by disseminating research as widely as possible. This study attempts to measure actual usage and dissemination or the report literature. Bibliometric studies like this one can help tract the effectiveness of dissemination strategies over time.

Researchers (or the interested public) are the intended audience for information published in technical reports. Digital dissemination makes reports available at no cost and conveniently. In providing bibliographic and physical access to the report literature publishers and librarians play a critical role in helping users locate and sometimes obtain technical reports. If databases do not index the report literature, that is one less way to users to find the information they need. It is recommended that the stakeholders use the type of research described in this study to work to create data a large amount of data in systematic fashion to make data collection more statistically significant and thereby contribute to the creation of better metrics to help understand the impact of technical reports.

Suggestions for Future Research

The results of this study suggest several directions for future studies. It would be interesting to analyze all the titles of the cited and uncited reports to see what words and/or concepts they have in common, determine the subject areas/disciplines of the research, look at which authors and institutions cited the reports, and analyze the co-author data to gather evidence of the degree of collaboration occurring between the laboratory and other institutions. The fact that some of the reports were not cited does not mean that they may not have been useful. Kaplan and Nelson (2000) believe that “uncitedness should not be equated with uselessness.

As a multi-program laboratory that carries out research for the Department of Energy, ORNL has a stated goal to “collaborate” with other organizations. The laboratory’s research activities fall under the heading of “big science” and one characteristic of big science as it is described by Price (1963) is team research. Since team research implies collaboration, this means that publications created within a team may have multiple authors. Collaboration is a valued goal of the institution because it is seen as a way for ORNL to increase its scientific productivity and visibility. This means laboratory management would have an interest in being able to measure the level of collaborative activity that takes place among its researchers in order to determine how well this goal is achieved. This information then could be shared with policy makers and funding agencies as evidence of research accomplishments and productivity. Other bibliometric studies (De Bellis, 2009) have shown that collaboration has been associated with higher research productivity. In analyzing the distribution of a set countries over internationally coauthored papers in the fields of biomedical research, chemistry, and mathematics Glanzel (2002) found that multi-authored papers were more likely to be cited and attract more citations than single-authored papers.

The set of reports identified for this study could be used in a more detailed comparison of the bibliographic elements in both the citing articles and the reports themselves. It might be revealing to see which references are listed/used in the technical reports in order to determine what literature this group of reports cites and how that relates to the references used by the journal articles that cited these reports. It might make it possible to trace the flow of ideas between this set of reports and the journals that cite them using co-citation analysis. Research analyzing interaction and flow between technical report literature and journal literature could generate information that can be used by policymakers to identify those scientific fields expected to have critical influence on industrial R&D and help them plan and implement scientific policies and monitor scientific research (Park & Keno, 2009).

By only examining the impact on two disciplines, this study barely scratches the surface of the usage of technical report literature. An examination of the report literature in other scientific disciplines where ORNL performs research (e.g. physics, biology, nuclear science or materials sciences) could provide additional knowledge regarding the use and impact of the technical report literature. Another dimension of this study could involve expanding the cited reference search window from the time the reports were published in 1992 and 2002 to the present. This would offer an opportunity to see whether the digitization of legacy reports make a difference in how the reports are cited. "Those who are familiar with technical reports often tend to think of publications from the Department of Energy (DOE), the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), and the Environmental Protection Agency (EPA) because these agencies have made an effort to increase access to their publications and are striving to digitize and make their older literature more available in digital format" (Oxnam, 2010).

Another direction that future research could take would be to compare the impact of technical reports issued by several of the other FFRDC institutions with reports published by ORNL. These institutions do similar kinds of research and, in some cases, are funded by the same government agency. Comparing their publication rates, funding and citation rates could be informative about the impact of technical reports. Information contained in technical reports provides knowledge that can stimulate new research or contribute to practical applications. The sponsoring agencies "who conduct, manage, and sustain the basic research disseminated in technical reports believe in its impact and its value and find it useful to assess the value of that information" (BES, n.d.).

Since this study was conceived, other citation database products have gained prominence as competitors and/or complements to the SCI product. The emergence of Google Scholar, CiteSeer and Scopus and other databases has caused scholars (Archambault et al, 2009; Meho, 2009; Noruzi, 2005) to raise questions about the validity of findings based exclusively on data from Web of Science. An advantage of Google Scholar is that it is not restricted in indexing different document types such as technical reports (Noruzi, 2005). Archives like Citeseer make it possible to freely access citation data for millions of documents (Rahm & Thor, 2005). Determining whether or how well the new citation databases cover the technical report literature would impact how useful they would be in a study of the technical report literature. In spite of some potential disadvantages, there could be some value in using multiple citation data sources to assess the impact of technical report literature in research.

Conclusions

Notwithstanding the fact that digital distributions of technical reports increases their physical availability, this study revealed that the transition from print to digital format of report generated by a federally-funded research institution has not had a visible impact upon the use of technical report for the years investigated.

In examining the report literature, this study shows that "virtually any publication can be examined bibliometrically" (Herubel,1999). The vast majority of bibliometric studies have been devoted to scientific and technological disciplines. Among the data gathered, characteristics of materials used and intellectual content of published materials can offer insight into the scholarly record both bibliographically and socially. Bibliometric methods also have gained adherents in science policy studies (Herubel,1999). Phenomena such as intellectual influence can be gathered from simple publication counts and the history of a given discipline can be mapped through the bibliographic record inherent in published documents (Herubel,1999).

Specific impacts resulting from technical reports are still not well understood and additional research (Walker, 1994; McClure, 1988) related to developing methods that measure the use and impact of the technical report literature is needed. It would be helpful to identify perceived versus actual barriers to the access and use of technical report literature and to conduct careful analyses of literature assessing the use of technical reports. It is not clear which types of activities benefit from what types of reports and how technical report literature has impact on those activities. Ultimately the goal of research efforts should be to determine the degree to which technical reports are an effective means to transfer the result of federal research and development results to the scientific and scholarly community.

The results of this study point out that more research is needed in order to have a better idea of the impact of the technical report literature. It might be more useful to identify a set of highly cited reports using SCI and then try to map the flow of information from the reports through the citing documents. In addition to citation counts, following the flow of funding through the institution that produces technical reports could be another way of gathering information about the impact reports have on the scientific and technical community.

Scientific and technical information is essential to technological innovation, but that information alone does not guarantee technological innovation. Therefore, understanding how scientific and technical information made available in technical reports is communicated as part of the process of technological innovation is critical for assessing the federal policies that influence the production, transfer, and utilization of information contained in technical reports (McCreadle, 1999). Open flow of information is essential to the exchange of ideas and this sharing of information is what keeps knowledge growing (Borgman, 2007; Craig, 2007). Since the report publishing pattern of ORNL is similar to that of other Department of Energy sponsored research institutions and can be considered representative of this group of national laboratories, the results of this study may be extrapolated to the group. It is hoped that this study has offered insight into the use of technical report literature.

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Appendix

APPENDIX A: Technical Report Output of Selected National Laboratories

Technical Report Output for Four National Laboratories from 1992 to 2002

Year	ORNL	ANL	LANL	LLNL
1992	720	170	104	137
1993	394	804	714	879
1994	344	986	1036	892
1995	323	761	684	922
1996	235	423	681	496
1997	268	293	674	449
1998	320	209	817	642
1999	152	213	429	679
2000	167	212	280	646
2001	250	195	134*	352
2002	133	218	175*	324

Report output for the laboratories compiled from data gathered from the NTIS and Energy Citation databases. Bibliographic information for the reports produced by the Department of Energy (DOE) laboratories is made available through these databases. There is some overlap in coverage, but neither database contains a comprehensive listing of the reports produced by the labs. The laboratories selected include Oak Ridge National Laboratory (ORNL); Argonne National Laboratory (ANL); Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory (LLNL). The reports identified are those available for public distribution. Totals differ from those reported in the study due to lack of report numbers and other inconsistencies or inaccuracies in the databases. The author makes no claim that these numbers are accurate totals for each laboratory. These laboratories are classified as Federally Funded Research and Development Centers (FFRDCs), research institutes which are contracted by a government agency to perform research and development (NSF 2010).

Appendix B: Data Coding Guide

Data Element	Operational Definition
Cited Report	ORNL report number as listed in the Cited References. Also indicate if report is not cited
Report Age	Report publication date
Report Format	1) Print; 2) Digital
Subject/Field	First subject listed in Subject Category field.
Citing Institution	Captured institution name in order to categorize as 1) University = any college or university; 2) Non-university = any institution that is not a college or university; 3) Other = any institution that does not fit either of the first two categories.
Institution Location	Captured country designation/affiliation represented by the address of the institution of the first author and categorized as 1) U.S; 2) Non-U.S.
Source	Journal Name
Source Year	Journal publication date
ISSN	ISSN is the unique numerical journal identifier that was used as an additional aid in accurately sorting and counting results based on the journal title.
Refereed Status	Yes or No (as indicated in Ulrich's Serials Directory)

Data elements for the study were captured from the ISI database as outlined in this guide and transferred into an Access database where the information was augmented by data from the Ulrich's Serials Directory (online product).

Appendix C: FFRDC Article Output in Chemistry and Engineering

Chemistry and Engineering Articles Published 1992 and 2002

Fields	**1992**	**2002**
All fields	198,864	187,400
Engineering	14,395	12,475
Chemistry	14,647	14,043

Information in this table was compiled from data in US National Science Foundation, Science and Engineering Indicators 2004 -- Appendix table 5-36; U.S. S&E articles, by field and sector, 1995-2005; APPENDIX TABLE 3. S&E article output (fractional counts) of major S&E publishing centers, by field: 1988–2003 ORNL and some of the other laboratories are defined as a Federally Funded Research and Development Centers (FFRDCs).

Appendix D: SCI Subject Categories of Journals Citing Technical Reports

1. Agricultural Engineering
2. Agronomy
3. Biochemistry & Molecular Biology
4. Biology
5. Chemistry, Analytical (Chemistry, Applied, Chemistry, Multidisciplinary, Chemistry, Physical)
6. Computer Science, Hardware & Architecture (Computer Science, Interdisciplinary Applications, Computer Science, Software Engineering, Computer Science, Theory & Methods)
7. Ecology
8. Emergency Medicine
9. Energy & Fuels
10. Engineering, Aerospace (Engineering, Civil, Engineering, Electrical & Electronic, Engineering, Environmental, Engineering, Industrial, Engineering, Manufacturing, Engineering, Mechanical, Engineering, Multidisciplinary)
11. Environmental Sciences
12. Forestry
13.Geochemistry & Geophysics
14. Geosciences, Multidisciplinary
15.Materials Science (Materials Science, Ceramics, Materials Science, Composites, Materials Science, Multidisciplinary)
16. Mathematics, Applied
17. Mechanics
18. Metallurgy & Metallurgical Engineering
19. Meteorology & Atmospheric Science
20. Multidisciplinary Sciences
21. Nuclear Science & Technology
22. Oceanography
23. Physics, Applied (Physics, Atomic, Molecular & Chemical, Physics, Fluids & Plasmas, Physics, Multidisciplinary, Physics, Nuclear, Physics, Particles & Fields)
24. Plant Sciences
25. Remote Sensing
26. Statistics & Probability
27. Thermodynamics
28. Transportation
29. Water Resources

Appendix E: Chemistry and Engineering Journals Citing Technical Reports

Chemistry Journal Titles

1. ACS Symposium Series
2. Analytical Chemistry
3. Applied Biochemistry and Biotechnology
4. Applied Geochemistry
5. Biological Trace Element Research
6. Chemical Society Reviews
7. Geochimica et Cosmochimica Acta
8. Intermetallics
9. International Journal of Hydrogen
10. Journal of Radioanalytical and Nuclear Chemistry
11. Propellants, Explosives, Pyrotechnics
12. Separation Science and Technology
13. Solvent Extraction and Ion Exchange

Engineering Journal Titles

1. 21st IEEE/NPSS Symposium on Fusion Engineering
2. Annual Review of Energy and the Environment
3. Applied Mathematical Modelling
4. ASHRAE Journal
5. **Brennstoff-Warme-Kraft***
6. Composites Part A
7. Computing Systems in Engineering
8. Environmental Science & Technology
9. **Hazardous Waste Consultant***
10. **IEEE/NPSS Symposium on Fusion Engineering 21st***
11. **IEEE Transactions on Parallel and Distributed Systems***
12. **IEEE Transactions on Power Delivery***
13. **IEEE Transactions on Robotics***
14. International Journal of Advanced Manufacturing Technology
15. International Journal of Heat and Mass
16. International Journal of Human Factors in Manufacturing
17. Journal of the Air and Waste Management Association
18. Journal of Cold Regions Engineering
19. Journal of Engineering for Gas Turbines and Power
20. Journal of Energy Engineering-ASCE
21. Journal of Guidance, Control, and Dynamics
22. Journal of Hazardous Materials

Engineering Journal Titles cont'd

23.Journal of Heat Transfer
24.Journal of Hydrology
25.Journal of Pressure Vessel Technology
26.Journal of Structural Engineering
27.Journal of Thermophysics and Heat Transfer
28.Ozone-Science & Engineering
29.Precision Engineering
30.Reliability Engineering and System Safety
31.Resources Conservation and Recycling
32.Tribology International
33.Transportation Research Part A
34.Transportation Research Record
35.Water Science and Technology
36.Welding Journal
37.Wear

Appendix F: All Citing Journal Titles and Refereed Status

Journal Titles
2003 Particle Accelerator Conference*
21st IEEE/NPSS Symposium on Fusion Engineering*
ACS Synposium Series
Advances in Agronomy
AIP Conference Proceedings *
American Ceramic Society Bulletin*
Analytical Chemistry
Annals of Emergency Medicine
Annals of Forest Science
Annaul Review of Energy and the Environment
Applied Biochemistry and Biotechnology
Applied Geochemistry
Applied Mathematical Modelling
ASHRAE Journal
Biological Trace Element Research
Biomass & Bioenergy
Bioresource Technology
Brennstoff-Warme-Kraft*
Bulletin of Environmental Contamination and Toxicology
Bulletin of the American Meteorological Society
Chemical Society Reviews
Chemosphere
Composites Part A
Composites Science and Technology
Computer Physics Communications
Computing Systems in Engineering*
Concurrency-Practice and Experience
Construction and Building Materials
Earth Interactions
Ekologia-Bratislava
Energy
Energy Policy
Environmental Fluid Mechanics*
Environmental Management
Environmental Science & Technology

Journal Titles (cont'd)
Environmental Toxicology and Chemistry
Fisheries Oceanography
Fusion Engineeringand Design
Fusion Science and Technology
Fusion Technology
Geochmica et Cosmochimica Acta
Geophysical Research Letters
Global Biogeochemical Cycles
Global Ecologyand Biogeography
Ground Water
Ground Water Monitoring
Hazardous Waste Consultant*
Health Physics
IEEE Parallel & Distributed Technology*
IEEE Transactions on Parallel & Distributed Systems*
IEEE Transactions on Power Delivery*
IEEE Transactions on Robotics*
Interdisciplinary Science Reviews
Intermetallics
International Journal of Advanced Manufacturing Technology
International Journal of Biometeorology
International Journal of Climatology
International Journal of Heat and Mass
International Journal of Human Factors in Manufacturing
International Journal of Hydrogen Energy
International Journal of Parallel Programming
International Journal of Remote Sensing
International Journal of Supercomputer
JOM
Journal of Applied Meteorology
Journal of Applied Physics
Journal of Climate
Journal of Cold Regions Engineering
Journal of Composites Technology
Journal of Computational Physics
Journal of Energy Engineering-ASCE
Journal of Engineering for Gas Turbines and Power

Journal Titles (cont'd)

Journal of Geophysical Research
Journal of Geophysical Research-Atmospheres
Journal of Geophysical Research-Biogeosciences
Journal of Guidance, Control and Dynamics
Journal of Hazardous Materials
Journal of Heat Transfer
Journal of Hydrology
Journal of Marine Systems
Journal of Materials Research
Journal of Nuclear Materials
Journal of Nuclear Science and Technology
Journal of Physics G
Journal of Pressure Vessel Technology
Journal of Radioanalytical and Nuclear Chemistry
Journal ofStatistical Planning and Inference
Journal of Structural Engineering
Journal of the Air & Waste Management Association
Journal of the American Ceramic Society
Journal of Thermophysics and Heat Transfer
Key Engineering Materials
Linear Algebra and its Applications
Materials at High Temperatures
Materials Science and Engineering A
Materials Transactions JIM
Mechanics of Time-Dependent Materials
Meteorology and Atmospheric Physics
Nuclear Engineering and Design
Nuclear Fusion
Nuclear Instruments & Methods
Nuclear Instruments & Methods in Physics
Nuclear Physics A
Nuclear Safety*
Nuclear Science and Engineering
Nuclear Technology
Ozone-Science & Engineering
Parallel Computing
Philosophical Transactions
Physica C

Journal Titles (cont'd)

Physical Review A
Physical Review C
Physical Review D
Physical Review Special Topics
Physics Letters B
Plant Biosystems
Precision Engineering
Proceedings of the National Academy of Sciences
Progress in Nuclear Energy
Progress in Particle and Nuclear Physics
Propellants Explosives Pyrotechnics
Radiation Effects and Defects in Solids
Radiation Protection Dosimetry
Reliability Engineering & Ssystem Safety
Remote Sensing of Environment
Resources on Conservation and Recycling
Review of Scientific Instruments
Reviews of Modern Physics
Reviews on Advanced Materials Science
Scripta Metallurgica et Materialia
Separation Science and Technology
SIAM Journal on Matrix Analysis
SIAM Journal on Scientific Computing
SIGPLAN Notices*
Solvent Extraction and Ion Exchange
Southeastern Naturalist
Transportation Research Part A
Transportation Research Record
Tribology International*
Water Resources Research
Water Science and Technology
Wear
Welding Journal
Zeitschrift fur Physik C
Highlighted (*) items are not refereed publications.

Appendix G: Citing Institutions, Number of Report Citations and Country

Institution	#Cites	Country
Alcoa	1	USA
Alfred University	1	USA
Allied Signal Auxiliary Power	1	USA
Amer Council Energy Eff Eco	2	USA
Argonne National Laboratory	7	USA
Arizona Sate University	1	USA
Auburn University	4	USA
B&W Nucl. Technol.	1	USA
BDM INT INC	2	USA
Belgian Nucl Res Ctr	1	Belgium
Bell Helicopter Textron Inc	1	USA
BRIJ RISK Res	1	Canada
Brookhaven National Laboratory	1	USA
Carnegie Inst Washington	2	USA
Carnegie Mellon University	2	USA
Case Western Reserve University	1	USA
CEA	1	France
CEN Cadarache	1	France
CERFACS	1	France
CFD Res Corp	1	USA
Chalk River Labs	1	Canada
Columbia University	1	USA
Deutsch Wetterdienst	1	Germany
Dornier Luftfahrt GMBH	1	Germany
Dupont Co. Inc.	1	USA
Electric Power Res. Inst	2	USA
Eth Zentrum	1	Switzerland
Fermilab National Accelerator Laboratory	1	USA
Florida International University	1	USA
Ford Motor Company	1	USA
Forschungszentrum Julich	1	Germany
Fraunhofer Inst Syst Tech & Innovat Forsch	1	Germany
Geological Survey of Canada	1	Canada
Georgia Institute of Technology	3	USA

Institution (cont'd)	#Cites	Country
Harwell Lab	1	UK
Hebrew University Jerusalem	1	Israel
Herndon Sci & Software Inc	1	USA
Hong Kong Polytech University	1	China
IBM Corp	1	USA
Idaho National Engn Lab	3	USA
Indiana University	1	USA
INFN, Sez Bologna	1	Italy
Iowa State University	3	USA
Japan Atom Energy Res Inst	2	Japan
Johns Hopkins University	2	USA
Kyushu University	2	Japan
Lawrence Berkeley Lab	5	USA
Los Alamos NationaL Laboratory	5	USA
Louisiana State University	2	USA
Mclaren Hart Environm Serv Inc	1	USA
Michigan Technological University	1	USA
Middle Tennessee State University	1	USA
MIT	4	USA
NASA, Lewis Res Ctr	1	USA
Natl Climat Data Ctr	1	USA
Natl Ctr Atmospher Res	1	USA
Natl Inst Fus Sci	1	Japan
Natl Inst Publ Hlth & Environm Protect	1	USA
Netherlands Energy Res Rdn	1	Netherlands
NIST	1	USA
NOAA	4	USA
Oak Ridge National Laboratory	120	USA
Ogden Environm & Energy Serv Co	2	USA
Pacific Northwest Laboratory	8	USA
Pacific NW Res Fdn	1	USA
Penn State University	2	USA
Petersburg Nucl Phys Inst	1	Russia
PIEAS	1	Pakistan
Princeton University	1	USA
PSRC	1	USA
Queens University Belfast	1	Ireland

Institution (cont'd)	**#Cites**	**Country**
Renewable Oil Int LLC	1	USA
Rensselaer Polytech Inst	5	USA
Rostsea, UNESCO	2	Indonesia
S Dakota State University	1	USA
Simon Fraser University	1	Canada
So Illinois University	1	USA
Spallation Neutron Source	1	USA
Supercomp Res Ctr	1	USA
Tohoku University	1	Japan
Transarc Corp	1	USA
University Alabama	1	USA
University Alberta	2	Canada
University Alcala de Henares	1	Spain
University Arizona	1	USA
University Bourgogne	1	France
University British Columbia	2	Canada
University of California, Davis	4	USA
University of California, Los Angeles	4	USA
University of California, San Diego	1	USA
University Chicago	1	USA
University Georgia	1	USA
University Illinois	3	USA
University of Maryland	3	USA
University of Michigan	2	USA
University Montana	2	USA
University Nat Resources & Appl Life Sic	1	Austria
University Nevada	1	USA
University Pavia	1	Italy
University Perpig	2	France
University Politecn Madrid	1	Spain
University Porto	1	Portugal
University Rhode Island	1	USA
University Rochester	3	USA
University Roma La Sapienza	2	Italy
University Tennessee	14	USA
University Tennessee, Space Inst	1	USA
University Tokyo	6	Japan
University Toronto	1	Canada

Institution (cont'd)	#Cites	Country
University Twente	3	Netherlands
University Waterloo	1	Canada
University Wisconsin	1	USA
PSRC	1	USA
Unknown	1	Unknown
US Dept Hlth & Human Serv	1	USA
US Dept Transportation	1	USA
US DOE, Environm Measurements Lab	1	USA
US Geological Survey	1	USA
Westinghouse Savannah River Co	1	USA
Wright Patterson AFB	1	USA
Yale University	1	USA

Vita

Cynthia Manley was born in Tuscaloosa, Alabama and grew up in Oak Ridge, Tennessee. She is the Technical Services Team Leader at Oak Ridge National Laboratory (ORNL) Research Library. She has been employed at ORNL Library since 1984 and has held a variety of positions within the library. Before working at ORNL, she worked at the Graduate Library at the University of Michigan in Ann Arbor. She holds a Bachelor's degree in Journalism and a Masters degree in Library Science from the University of Tennessee in Knoxville. She is a past-president of the Tennessee Valley Chapter of the Special Libraries Association (SLA) and the current Webmaster for the chapter's website. She has been a member of the American Library Association (ALA), the Association for Library and Information Science Education (ALISE), the Tennessee Library Association (TLA) and the American Society for Information Science and Technology (ASIST). Her research interests include the impact and diffusion of information technology, information use, bibliometrics, and library marketing.