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The many faces of *accessibility*: engineers' perception of information sources

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Abstract

Numerous studies of engineers' information seeking behavior have found that accessibility was the factor that influenced most their selection of information sources. The concept of *accessibility*, however, is ambiguous and was given various interpretations by both researchers and engineers. Detailed interviews with 32 engineers, in which they described incidents of personal information seeking in depth, uncovered some of the specific factors that are part of the concept. Engineers selected sources because they had the right format, the right level of detail, a lot of information in one place, as well as for other reasons. When looking for human information resources, the engineers most frequently selected sources with which they were familiar, while saving time was the most frequently mentioned reason for selecting documentary sources. Future research should continue to examine the concept of *accessibility* through detailed empirical investigations.

Keywords: Engineers' information behavior; Selection of information sources; Accessibility; Human information sources

1. Introduction

Engineers were among the first to be studied as users of information. While various theories and frameworks have been developed for the study of human information behavior (see, for example, the review article by Pettigrew, Fidel, & Bruce, 2001), the study of engineers' information

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seeking behavior began without any theoretical or conceptual guidance. Following the early series of studies by Allen (1977), several researchers investigated aspects of engineers' information seeking behavior, such as the information channels used, the factors that affected channel selection, and the social networks that supported information seeking activities. These investigations have generated a few themes relating to general patterns in engineers' behavior.

Studies have shown repeatedly that engineers rely most heavily on internal sources for information, mainly on interpersonal communication with colleagues. Further, the accessibility of an information source is the most prominent factor affecting its use (see, for example, review articles by e.g., Leckie, Pettigrew, & Sylvain, 1996; Pinelli, Bishop, Barclay, & Kennedy, 1993). While numerous studies have examined the concept of *accessibility* as a variable, there is still no common understanding of the specifics involved. The study reported here asked engineers to articulate in their own words the factors that affected their choice of an information source. The results revealed that there were many faces to *accessibility*, and that the roles that they played changed with the nature of the information source, whether human or documentary.

2. The use of the concept *accessibility*

An information source that is most accessible is one that requires the least effort of the engineer who wants to access it (Anderson, Glassman, McAfee, & Pinelli, 2001). The finding that accessibility was the major factor in the selection of an information source indicated that engineers wanted to minimize their efforts. But there are many kinds of efforts, and the concept *accessible* by itself did not explain what kind of effort was being saved. In an early study about the role of accessibility in the use of information sources, Gerstberger and Allen (1968) examined the cost associated with using certain information sources, that is, the effort involved. Based on previous studies, they made a distinction between two kinds of effort: psychological and physical. To assess the psychological effort they measured the *ease of use* of an information source, and to assess the physical effort they measured *accessibility*.

Both concepts have been used as variables in numerous studies, but the distinction between them was not always clear. Rosenberg (1967), for instance, who examined the effect of *ease of use* on the method of gathering information among professional personnel in industrial and government organizations, concluded that further examination of the factors involved in this concept was needed. His study, like others, did not define the concept *ease of use* and at times it was used interchangeably with *ease of access*. Generally speaking, it is possible that engineers themselves did not make a distinction between these two facets. In the preliminary interviews for the present study, the engineers explained that the most important criterion for ways to search for information was *ease*. When asked to clarify the specifics, the participants described that ease implied all: saving time, saving mental effort, convenience of use of format, and maximum physical proximity. Obviously, these engineers wanted both *ease of use* and *ease of access* without any distinction between the two. Matters are even more complicated in most studies because the nature of the study methods that were employed made it very difficult to clearly define these concepts.

Most investigations used questionnaires or structured interviews to collect data (Pinelli et al., 1993, p.186). They required quantifiable responses from participants so that the effect of these variables on the use of information sources could be measured. Two approaches to data collection were common. In one, the respondents ranked information sources from a given list according to their accessibility and ease of use. In the other, respondents used scales to rate each information source in relation to each of the variables. The concept of *accessibility* was usually considered self-explanatory, and respondents applied their own meanings.

Due to the elastic semantics of *accessibility* in various studies, investigators actually have looked at different construals of the concept when they presented and interpreted the results of their studies. For example, Gerstenfeld and Berger (1980) had a general interpretation and included in their definition of *information access* the amount of time spent searching for information, regardless of the nature of the effort exerted during that time, whether physical or intellectual. Pinelli et al. (1993), on the other hand, read *accessibility* as the physical distance between the engineer and the information source. They supported this interpretation by citing research results showing that engineers whose offices were in close proximity to the library used it more often than those whose offices were farther away. But Cool and Xie (2000), who collected data from engineers in a corporate environment, found that information specialists and librarians were among the most accessible sources, more so than people in the engineers' own department or division. It is reasonable to conclude that these engineers did not think about physical distance when they rated librarians on the accessibility scale.

The introduction of the Internet, with email and the Web, into the everyday work of engineers has confounded the concept of *accessibility* even further because it is difficult to assign a physical distance to virtual sources. An early study about the use of electronic networks found that by the end of 1991, 84% of aerospace engineers had access to networks, 78% of them used them for email and 77% for information retrieval (Bishop, 1992). The numbers are probably much higher today. Clearly, engineers use the Internet to communicate with other people and to retrieve documents, whether internal or external to their organizations. This makes the physical distance between engineers and several information sources less critical because they can access both documents and human experts from their desktops. For example, engineers can access colleagues in their organization and those outside it through email with the same amount of effort. How can one explain, then, the finding of Cool and Xie (2000) that engineers perceived people outside their organization with whom they did not collaborate much less accessible than those in their work group? The investigators reported that the difference was 2.6 vs. 4.31 on a 1–5 scale, with 1 being not accessible. Clearly, these engineers considered factors other than physical distance. In fact, through interviews the researchers found that the main obstacles were indeed very different. The engineers perceived these people less accessible because experts outside the organization may require fees for their services, and because the engineers felt that their interactions would be limited because of proprietary concerns (Xie, 2002).

It is conceivable that most of the above mentioned researchers were not attentive to the multiple interpretations of *accessibility*. As Gerstberger and Allen (1968) explained, the purpose was to examine the *perceived* notion of accessibility. This is because engineers' behavior was guided by their own perceptions, not by what researchers believed *accessibility* to mean. Indeed, if one is motivated to study the sociology of engineers, the specific interpretation might not be crucial. It is enough to discover that the perception of accessibility leads to the engineer's choice of an information source. But if one is interested in improving information systems and services to better facilitate engineers' information seeking behavior, the specifics are highly relevant. It is vital to understand, for example, whether a magazine article is considered of low accessibility because it is difficult to understand, because it is difficult to retrieve on the Web, because it cannot be displayed clearly, or because it does not have enough tables and charts.

We can clearly state now that the prominence of *accessibility* has been established. It is time to unlock this black box and reveal the various faces of accessibility. In the study reported here, engineers described cases in which they looked for information to solve a work problem. The analysis of these descriptions provided the first systematic attempt to explicate the concept of *accessibility*.

3. Research method

The purpose of the study was to explore how engineers working in a particular organization sought information: what types of information needs they had, what sources they used, and how they selected these sources. The study employed a variant of the critical incident method (Patton, 2002), in which individual cases of information seeking were investigated in depth. Thirty-two engineers from a large manufacturing company volunteered to participate in the study and to report about incidents in which they looked for information. To collect the data, researchers conducted two interviews with each engineer.

The Cognitive Work Analysis framework (Rasmussen, Pejtersen, & Goodstein, 1994; Vicente, 1999) guided the interviews. This work-centered framework was developed as a general approach to help information system designers analyze and understand the complex interaction between (a) the activities, organizational relationships, and constraints of work domains, and (b) users' cognitive and social activities and their subjective preferences during task performance. In the first interview researchers asked general questions about the engineers, their work context, and the methods they usually employed to look for information. This interview collected information about the task in which an engineer was involved, the cognitive decisions and mental strategies required for the task, and about a number of personal characteristics such as experience and expertise. The second interview focused on particular incidents.

At the end of the first interview, the researcher explained to the engineer the nature of the second interview. To prepare the engineers for the second interview, the researcher asked the engineer to recall a recent instance in which the engineer was looking for information. The researcher then asked the engineer the questions designed for the second interview. This procedure gave the engineers a preview to the questions that would be asked in the second interview.

In addition, the engineer agreed to fill in a journal during the day before the second interview to document all the incidents of information seeking that occurred that day. Using the journal, engineers recorded brief notes for each incident about: the time, the information problem involved, what the engineer did to solve the problem, how successful the engineer was in resolving the problem, and the length of the process. The purpose of the journal was twofold: (a) to help engineers reconstruct the incident about which they were reporting, and (b) to recognize incidents of information seeking by recording them. The journal was in the form of a slender booklet the engineer could carry in a pocket, with each page dedicated to one incident.

At the beginning of the second interview the researcher examined the engineer's journal and selected three to four incidents. The researcher then focused on each incident and asked the engineer a set of questions that described in detail that particular incident and its context, including explanations about the problem itself, the method they used to look for information, and whether or not they found what was needed.

All the interviews were transcribed. These transcriptions provided the data for analysis. Because of technical problems with recording the interviews, not all were usable. A review of the transcribed interviews yielded 58 usable interviews from a total of 31 engineers. In these interviews, the engineers described a total of 117 incidents of information seeking, an average of 3.8 incidents per engineer.

Three members of the research team then analyzed the transcribed interviews using content analysis. Content analysis may focus on any aspect of the content of the material that interests the researcher, and it is reliable to the extent that the rules are precise, understood by the content analyst, and consistently applied. In this study, categories in three broad areas of information seeking behavior were of interest:

- Types of information sought
- Sources used to find information
- Factors used to select information sources

The research team met first to analyze a set of interviews to establish the first categories in each area. The categories included only those that could be derived from the interviews. Researchers then began to analyze interviews individually once the team felt that the categories were well enough developed. To increase the internal reliability of the results the three analysts were trained according to a prescribed set of rules. Further, all interviews were independently analyzed by two analysts. The analysts then compared their results to clear up any discrepancies. Finally, the research team met at least once a week to discuss new categories that had emerged, and to resolve any discrepancies that the analysts were unable to resolve on their own.

The categories that were established through this process, and the frequency with which they were used, were the major findings of the study. Here we focus on the third area of information seeking behavior—factors that the engineers used to select information sources—because it is the only one to directly contribute to our understanding of the specific factors that can play a part in engineers' perception of the concept of *accessibility*.

4. The participating engineers and their work

The 32 participating engineers had diverse educational backgrounds and expertise. Many of the participants held at least a Bachelor of Science, the majority had Master's Degrees and one had a Ph.D. Their areas of expertise included software engineering, logistics, hardware design, automatic test systems, digital systems processing, sales, structures and stress analysis, computer operating systems, instrumentation development, electromagnetics, and electronic receivers. In addition, several of the engineers reported having had additional training within the company in the areas of antennas, satellite communications, management leadership, artificial intelligence, avionics, aerodynamics, structures, and systems engineering.

While the average number of years in the profession was 17.6 years, the actual numbers ranged from 2 to 30 years. Most respondents had been in the profession for 10 or more years and only two had less than 4 years of experience in the profession. The average time at the company was 14.4 years, and only four engineers had been at the company less than 10 years. The engineers reported being in their particular unit in the company for an average of 3.1 years, with only four having been in the same area for more than 5 years, and one having been in his area for only one month.

With regard to their professional responsibilities, the participants reported working in a diverse range of areas, such as communications, navigation systems, design of co-generators, spacecraft engineering, software development, management, and customer support, to name a few. Within these areas, the engineers carried out a variety of functions, such as designing a working system, testing electronics and building test equipment, satisfying customer needs, selling products, performing statistical risk analysis for failures on engines, and finding new ways to process radar. Although some worked individually, often they worked as part of teams, some as leads.

Carrying out these functions, the engineers made many different types of decisions. Among others, these decisions included: representing things accurately, coding efficiently, overall simulation design architecture, selecting what parameters to test, choosing the right person for a particular job, deciding how to do the task, deciding where to spend money, deciding what to develop and what not to develop, deciding what needs attention first, on what assumptions to base analysis on, and task order.

To perform these functions, engineers were engaged mostly in office work: word processing, data analysis, writing code and other computer work. Outside of the office, engineers were responsible for setting up test equipment, going on tests, doing lab work, working directly with the product, and attending meetings. These activities were carried out for various purposes, such as to ensure customer satisfaction, extract more information, ensure quality of the product, determine organizational impacts, and ensure structural integrity.

Performing their tasks, the main constraints on the engineers' work were time and budget. These were the main factors that determined the extent and boundaries of the tasks they performed. Time constraints included the time within which to finish the project and the amount of time one might have to give to a project. Budget constraints included the amount of money available to complete or proceed with a particular task. Additional factors that the engineers considered included the larger goals of the organization, the union, and customer satisfaction.

As professionals, the engineers were rather independent in taking the responsibility for their tasks. Asked when a task was considered to be completed, the participants' responses varied. Many said that tasks were never really finished. Some indicated that the job was done when the money ran out or the budget was canceled. However, others used more quantitative criteria, such as when the test satisfied certain criteria, when a product demonstrated what it had been designed to do, when the question was answered, or when they had successfully removed the problem parts. Still others used different criteria such as personal judgment, or that of the team lead or management. A few even had checklists to guide them. Often the decision was made in conjunction with the group, either with the help of the lead, or other members, or with outside people. While customers and manufacturers had their own criteria, primarily it rested on the engineers themselves to determine when a task was completed.

The participating engineers mentioned various priorities they had when they worked on their tasks. Most common were the desire to secure safety, efficiency, and good communication among all involved in a project. Some engineers explained that for a task to be performed well it was important to understand the requirements of a task, work according to the schedule, make sure data were correct, and to deliver the best possible product. In addition, many said their goals were similar to those of the company: turning a profit, ensuring the safety and reliability of the products, working to promote customer satisfaction and staying with current, "leading edge" trends.

Collaboration was a way of life for the participating engineers. They cooperated with many different people in the course of their work. Most stated that they worked closely with several other units within the company, often those with a similar or related focus. In fact, most of the participants listed many groups with whom they cooperated, some within the company, some outside. In addition to groups that worked on related tasks, many of the engineers said that they worked also with people in finance, customer support, and sales.

The engineers explained that the chief method of communication with peers and co-workers were email, phone, and face to face. Some posted to a server or posted documentation on the Web to communicate with peers, and a few saw meetings as a vehicle for communication.

5. The many faces of *accessibility*

To identify the specific factors of accessibility respondents used when they decided which information source to use, we asked them about the reasons for choosing each source to meet a stated information need. In the data analysis, we examined each reason for source selection an engineer mentioned and assigned it to a category. The list of categories, or 'factors for source selection,' was developed in two stages. In the first stage, the five researchers read together interviews sequentially and through discussion, created the first factor for source selection according to the first reason the team encountered, then for the second, and so forth. Usually, a category was more abstract than the reason that generated it. Clearly, some interpretation was required for creating the categories and for assigning a reason to a category. For instance, one interviewer asked, "What criteria would you use to decide to go to the Web?" The engineer responded, "... because it is at my desktop," which was interpreted as "The source is physically close."

After reading four interviews together, all researchers performed the analysis of the next five interviews individually, and then came together to discuss their analysis and to continue the creation of the categories. At the end of this process, the list of categories seemed to become relatively stable. In the second stage, a team of three researchers analyzed all the interviews according to the list of categories, or factors, as explained in Section 3. A few factors were added during that stage. Throughout data analysis, a factor was recorded only if an engineer mentioned it explicitly as a specific reason for choosing a particular source.

5.1. The specific factors of accessibility

The analysis of the data collected through the 117 critical incidents uncovered eleven specific factors that can contribute to an engineer's perception of the concept of *accessibility*. These factors, in addition to the general concept itself, are presented in Table 1.

Table 1
Specific factors associated with *accessibility*

Sources I know	The respondent had used the source before and knew how to find it, how to use it, and its suitability for the situation. This category was chosen when the response indicated familiarity. The source might have been a person the engineer knew—or with whom the engineer had worked before—or a documentary source. As to the kind of efforts saved, approaching a familiar source definitely reduced the intellectual efforts involved in first-time interaction. At times, however, it might also have reduced physical efforts when one knew, for example, that the source had all the needed information and thus eliminated the need to look elsewhere
Has a lot of different types of information in one place	This factor was based upon a source's ability to provide many different types of information. Selection of such a source related to a desire to find the answers needed in one place rather than having to seek information in additional locations, and thus minimize the need to look at in several sources. An example is a respondent's statement that he used the Web "because it hits so many places so easily"
Can give the right level of detail	The right level of detail was a factor when an engineer wanted either a broader overview or a more detailed description than could be obtained from other sources. Selecting such a source made it unnecessary to look for additional sources, and thus cut down on search efforts. At times, a particular source was the only one that could give the required level of details
Saves time	Time, for this analysis, referred to the ability of the source to answer a question quickly. This was not to be confused with the notion of urgency, when a source selection was based upon the urgency of the need itself. For example, when asked the reason she chose people as sources of information, one engineer replied, "I think it's faster than me looking in a manual." Another engineer used personal files that "let me zero in on it relatively quickly." The concept *time saving*, however, is as multifaceted as *accessibility* because time can be saved in many different ways. When engineers selected a source that would save them time, they meant to lower both their efforts and the time spent on information retrieval
Has the right format	A reason for choosing a particular source over others was sometimes its format. In some cases the participants preferred paper sources, and electronic sources in others. Having the desired format could lessen intellectual efforts because it was easy to use the information. For example, if data was presented in a format that was compatible with one the engineer already used, there was no need to figure out how to convert it. It could also reduce the physical efforts because no transformation from the current format to a more desired format was required
Sources with which I feel comfortable	The engineers often chose people as sources based upon a level of comfort or association the respondent had with this person. For example, one engineer stated, "We have developed a pretty nice little network, and actually a lot of us are friends outside the company, so there is a certain comfort level, and it's nice to feel that you can go and ask them." This factor reveals the psychological facet of accessibility
Is physically close	Source was located in the immediate work area of the respondent so it was quickly and easily obtained. For example, a respondent used the Web

Table 1 (*continued*)

	"because it is at my desktop. It is a lot easier going to the Web and doing a quickie search than getting in my car and driving to the library"
Can be searched with keywords or codes	Electronic sources were selected because of the access to information provided by keyword or code searching
Is interactive	The source was chosen because the respondent needed to interact with the source. This interaction made it possible for an engineer to hold a dialog during the information seeking process. For example, when searching the library catalog, it could be helpful to refine the search in response to too few or too many results from the initial search. Similarly, people who are known to readily accept follow-up questions were considered interactive. While source interactivity may always be assumed to be beneficial, we only applied this factor when the source of information was preferred to another because of this ability to establish a reciprocal relationship. We assumed that engineers who selected a source for this reason did so because it would save them time and mental efforts
Is available	The simple fact that a particular source was available at a particular time, while others were not, was cited as a factor in source selection. For example, an engineer explained that she turned to a technician for information about an office machine because he seemed to be free to answer her question. Another one explained that he made his source selection based on the source's schedule. This factor was different from physical proximity because it might connote other dimensions, such as time or whether or not the source was proprietary. This factor brought a new meaning to the concept of *accessibility* because it did not translate directly into the amount of effort required
Is not busy	This factor was applied only to people as sources of information. It dealt with accessibility as it applied to choosing a source based upon whether he or she was otherwise occupied. There was an aspect of ease in this approach, as well as an element of time to be taken into consideration. One source was selected because, as the engineer noted, "he has much more time." Similar to "is available," this factor did not reflect a desire to minimize efforts
Is accessible	This was a catchall phrase. Because this analysis was based on responses to open-ended questions, we could not always choose the level of specificity in the engineers' responses. At times, engineers explained that they selected a source because it was accessible, or handy, without elaborating in what way. Such cases were recorded here

While all these factors were mentioned by the participating engineers, some were mentioned more frequently than others. Table 2 reports the number of times each factor in selecting sources was mentioned, and the percent of times among the accessibility factors, in descending order.

The results showed that physical proximity, while an important factor in source selection, was not the reason most frequently used by the participating engineers. For them, being familiar with a source of information was a much more influential factor. Similarly, the engineers considered an information source that can give information quickly as highly accessible.

Although previous studies rated physical proximity as the highest factor in the selection of an information source (e.g., Pinelli, 1991), one cannot claim that the results here are in complete

Table 2
Frequency distribution of accessibility factors for all information sources

Accessibility factors	Total instances	(%)
Sources I know	25	25
Saves time	19	19
Is physically close	11	11
Has the right format	9	9
Can give the right level of details	8	8
Is accessible	8	8
Is available	7	7
Has a lot of different types of information in one place	4	4
Sources with which I feel comfortable	3	3
Can be searched with keywords or codes	3	3
Is interactive	3	3
Is not busy	1	1
Total	101	101[a]

[a] The total is more than 100% because of rounding.

contradiction. Any comparison between this and previous studies should be made with the greatest caution because of the differences in the research methods used. Previous studies asked engineers about their general perceptions, while this study analyzed actual cases and examined the frequency in which the engineers actually used these factors. We have no evidence that engineers considered important only those factors they used frequently. It is possible that an engineer considered a certain factor of high priority but was not frequently in a situation in which the factor presented itself. Therefore, it is possible that while engineers considered physical proximity the most important factor, they might not have addressed the issue most frequently. This makes sense with the increase in the availability of information in an electronic form, which created a situation in which the engineers do not have to consider the physical proximity as frequently as before. At the same time, they may still consider it the most important factor.

5.2. Accessibility vs. quality

In explaining their reasons for selecting an information source, not all factors mentioned by the engineers related to accessibility. Other factors addressed attributes of the *content* of the information the source carried and could be attributed to *quality*. The engineers identified seven quality factors, which are given in Table 3.

Although the engineers mentioned factors associated with quality, accessibility was the most frequent reason for source selection. Accessibility factors totaled 68% of all instances in which the engineers reported on factors they used (148 instances). Yet, some quality factors were prominent as well. Their ranking among the top 10 most frequent reasons is shown in Table 4.

As the ranked list in Table 4 shows, the engineers in this study paid much attention to quality. In fact, if one removes the distinction between "Can give data that meets the needs of the project" and "Is most likely to have the information needed" and collapse the two factors to one, this newly created quality factor would rank first, covering 23% of the factors. These results are

Table 3
Specific factors associated with *quality*

Can give data that meets the needs of the project	The source was selected because an engineer *was certain* that it had the necessary information to satisfy project information needs. Since the respondents rarely used those precise words, judgment was required in deciding when a response was sufficiently explicit to be counted. For example, a respondent said, "if I am looking specifically at a [the company] project, then I will stick with the [company] net. If I am looking for something that is ... coming from the outside world, I will generally ignore the [company] net and go directly to the outside world...." That statement was determined to be sufficient indication that the ability to meet the project needs was a reason for choosing a particular information source. Often, this category was used when the source was previously known to have the information needed
Is most likely to have the information needed	This factor differs from the previous one in that an engineer *believed* that it was the source most likely to meet the need, but was not completely sure. For instance, a respondent indicated that the "first place to go look for it is [a certain database]", implying that the database was most likely to yield the needed information, but that it could be necessary to look at a second or third source
The information is not available elsewhere	A source was selected because it was the only one that was likely to have the information needed. For example, one engineer stated that he chose to speak to a particular person because "... a lot of the knowledge is not written anywhere..." and another explained a source selection because "... no one else is going to know the code." This factor was applied only to human sources
Can give the latest information	The information contained in the source was up-to-date
Is reliable	The source was consistent and dependable. For example, one respondent used a source because it was "a standard in the industry"
Gives definitive answers	The source provided specific information that answered an engineer's questions. Using this source required no additional speculations or interpretations
Is accurate	An engineer chose a source because he or she trusted the accuracy of its information

different from those of previous research. Numerous studies have concluded that engineers were mostly concerned with the accessibility of information sources and were not motivated to select a source by the quality of the information in it (e.g., Gerstberger & Allen, 1968; Hardy, 1982; Rosenberg, 1967). Here again, the difference in the findings might have resulted from the dissimilarity of methods used. It is possible that while in actuality engineers considered the quality of the information in a source, when asked about their general perceptions they did not rank this factor highly. It is also possible that the experience of using the Web heightened engineers' awareness of the quality of the information in an information source because much of the information they retrieve from the Web is not relevant to their needs.

The prominent role of information quality gives rise to the idea that the distinction between *accessibility* and *quality* is blurry at times. For example, it is possible that familiarity, the most

Table 4
The top 10 factors affecting the selection of information source

All factors	Total instances	(%) $N = 148$[a]
Sources I know *(accessibility)*	25	17
Can give data that meets the needs of the project *(quality)*	21	14
Saves time *(accessibility)*	19	13
Is most likely to have the information needed *(quality)*	13	9
Is physically close *(accessibility)*	11	7
Has the right format *(accessibility)*	9	6
Can give the right level of details *(accessibility)*	8	5
Is accessible *(accessibility)*	8	5
Is available *(accessibility)*	7	5
Is reliable *(quality)*	7	5

[a] The total number of reasons for source selection in the 117 cases was 148.

frequently cited reason, is actually related to both accessibility and quality. One may turn to a familiar source to save effort, but also because one knows the source is likely to have the information of the desired quality. Gerstberger and Allen (1968) have already suspected the close relationships between these two concepts in the minds of the engineers they studied, even though they concluded that accessibility "almost exclusively determines frequency of use." The distinction between these two concepts in the minds of engineers should be investigated further. Additional examinations are required to study the concept of *quality*, how it is different from *accessibility*, and how it can be represented when considering the quality of information for engineers.

5.3. Human vs. documentary sources

One of the most highly cited results from early studies of engineers' information behavior was the heavy use they made of human information sources. Allen (1988) explained that unlike scientists, engineers did not use documentary sources frequently because the nature of their product was not text to be read or spoken, but rather an actual artifact. Hertzum and Pejtersen (2000) took a different view. They conducted two case studies and showed that the nature of information an engineer needed determined whether a human or documentary source was sought. For example, documents were used when an engineer needed information about materials to be used in manufacturing, but human sources were the best sources—and possibly the only ones—when an engineer wanted to understand the priorities of a design project. Similarly, Ellis and Haugan (1997), who studied 23 engineers in an R&D company, explained the use of different sources by the type of a project and its various stages.

The engineers who participated in this study turned to people for information 40% of the times, and 97% of the participants consulted a human source at least once in the cases they described. This was not surprising because in 53% of the cases, the information sought was internal to the company and dealt with local procedures, priorities and interpretations. Quite often this type of information was not documented and was available only from human sources.

To examine whether the factors of accessibility that were employed when looking for a person as an information source were the same as those used for documents, we calculated the frequency

Table 5
Frequency distribution of accessibility factors for human information sources

Accessibility factors for human sources	Total instances	%
Sources I know	20	50
Saves time	6	15
Is physically close	4	10
Is accessible	3	7.5
Sources with which I feel comfortable	3	7.5
Can give the right level of detail	1	2.5
Is available	1	2.5
Is interactive	1	2.5
Is not busy	1	2.5
Has the right format	0	0
Has a lot of different types of information in one place	0	0
Can be searched with keywords or codes	0	0
Total	40	100

Table 6
Frequency distribution of accessibility factors for documentary information sources

Accessibility factors for documentary sources	Total instances	%
Saves time	13	22
Has the right format	9	15
Is physically close	7	12
Can give the right level of detail	7	12
Is available	6	10
Is accessible	5	8
Sources I know	5	8
Has a lot of different types of information in one place	3	5
Can be searched with keywords or codes	3	5
Is interactive	2	3
Sources with which I feel comfortable	0	0
Is not busy	0	0
Total	60	100

of these factors for each type of source separately. The results for human sources are presented in Table 5 and those for documentary sources in Table 6.

These results indicated that the accessibility of human sources had dimensions that were different from those for documentary sources. While familiarity with the source ("Sources I know") was by far the most frequent reason when selecting a human source for information and was used in 50% of the cases with human sources, it was employed only 8% of the times when looking for documents. Similarly, saving time was the most frequent reason for selecting a documentary source, but only in 15% of the cases where engineers selected human sources did they do so in order to save time.

6. Discussion

The overall purpose of the study presented here was to identify the types of information problems the engineers had, the sources they used to solve these problems and the reasons for their selection of these sources. While the study did not set out to uncover the various meanings of *accessibility*, the rich data collected made it possible to explore this concept and its use. As a result, the findings presented here are only suggestive. They point to the complexity of this concept and to the need for further examination of its multiple meaning. They also indicate that the common research approach, in which engineers are asked to rate the accessibility of various information sources, is limited in its ability to guide the improvement of information systems and services.

6.1. The need to examine the concept of accessibility

The concept of *accessibility* is central to information science. Much of the research in information science is carried out with the ultimate goal of improving access to information. Therefore, any examination of what is involved in the accessibility of information sources has the potential to offer a valuable contribution. Previous studies aimed at capturing engineers' perceptions and have made a distinction between physical accessibility (*accessibility*) and intellectual accessibility (*ease of use*). This distinction dominated not only the research instruments used, but also the interpretation of the results. For example, researchers accepted with no further investigation the finding that engineers use their co-workers as a prime source of information. Such findings made sense when physical proximity has been determined to be the main factor for source use (e.g., Pinelli, 1991). But it is possible that physical proximity is not the main reason that co-workers are a major information source. The results of this study show that when engineers expressed their perceptions in their own words, they most frequently mentioned that being familiar with a person was the reason for selecting a human information source. It is possible, therefore, that consulting co-workers takes place not because of physical proximity, but because of familiarity, which is most likely to minimize intellectual effort. This example illustrates that explaining study results based on the division between the physical and the intellectual may not always reflect reality. Currently, we do not know why engineers who participated in previous studies perceived their co-worker as accessible information sources because past studies did not ask this question.

Moreover, the engineers who participated in this study made very little distinction between the two aspects when asked to express their perceptions in their own words. While some of the reasons they mentioned for selecting an information source clearly represented one aspect or another, in most cases the reasons could be construed to include either or both aspects. For example, the most frequently used reasons, "Sources I know" and "Saves time," which in total were used in 44% of the cases (see Table 2), may represent the saving of both physical and intellectual effort.

There were few instances in which the engineers did make this distinction. In cases when they clearly expressed preference for close physical proximity they explained that the source "Is physically close" (11% of the cases). They expressed a clear desire to save intellectual effort when they noted that a source "Can be searched with keywords or codes" (3%) or when it "Is interactive" (3%). In some cases the engineers wanted to save emotional effort and turned to "Sources with which I feel comfortable'' (3%). It seems, therefore, that the distinction between physical and intellectual effort was not foremost on the engineers' mind. In only 20% of the cases did the reason they articulated express either physical or intellectual effort. The rest of the factors, such as ''sources I know'' and ''saves time'' could be either one or both (see Table 2). While attractive on the theoretical level, this distinction might not be most useful for studies that aim to uncover engineers' perceptions in order to inform the design and evaluation of information systems and services.

Data analysis revealed a new aspect of *accessibility*; that of *availability*. Unlike *accessibility*, *availability* is not associated with efforts. *Availability* points to the fact that it was possible to use a source at a particular time. In 8% of the cases engineers selected a source because they felt it ''Is available,'' or because it ''Is not busy'' (see Table 2). These aspects have not been addressed before in studies of engineers' information seeking behavior. Although Chakrabarti, Feineman, and Fuentevilla (1983) have already used this term in a questionnaire they sent to 1000 engineers and scientists in an R&D corporation, they did not provide a definition or explanation of what was included in the term. Their study measured other variables, such as *ease of use* and *cost*, but did not use the term *accessibility*. It is plausible to assume that these researchers just used another term to express the concept of *accessibility*.

Clearly, with this multitude of interpretations for the concept of *accessibility*, it might be time to abandon the concept altogether and employ more directed and specific concepts—such as those uncovered in this study—when looking for factors that affect the selection of information sources.

6.2. Human vs. documentary sources

While separating the intellectual from the physical, most previous studies have addressed information sources on a general level without making a distinction between the factors involved in the selection of documentary information sources and those involved in choosing a human source. This approach is beginning to change as a few recent studies have made the distinction between the two types of sources. Anderson et al. (2001) focused on documentary sources only, which they called written sources. [2] They received 872 responses to a questionnaire from engineers and scientists in the aerospace industry. The authors' data analysis revealed that accessibility was not a predictor of documentary source selection. Instead, ''importance to one's work'' was the primary factor in the decisions to use such sources. Hertzum and Pejtersen (2000) arrived at similar conclusions. Their data showed that while cost and time were the most prominent barriers to the use of both types of information sources, containing ''irrelevant information'' was the second barrier for documentary sources, and ''intellectual/social effort'' for human sources.

The results of the study reported here follow this trend. They clearly show that the top reasons the engineers employed to select a human source were different from those for documentary ones. In 50% of the cases when engineers selected a human source, they did so because they were

[2] The reference to oral or written sources—meaning people and documents, respectively—is misleading. The sources themselves are not either oral or written. It is rather the information they provide that can be characterized this way. Moreover, interaction with human sources can be written (as in email messages), and documents can be oral (as in audio files on the Web).

familiar with the person (see Table 5). This factor was used only in 8% of the cases when documentary sources were selected (see Table 6). The most frequent motivation for selecting a documentary source was to save time (22% of documentary cases), which was second in rank for human sources (15%). Moreover, the factor second in frequency when selecting documentary sources was the need for a certain format (15%). This factor, however, was not pertinent for human sources at all. Similarly, while engineers turned to a person with whom they felt comfortable in 7.5% of the cases, they never expressed this reason when using a documentary source.

These findings are highly relevant for research that aims at the evaluation and design of information systems and services. Suppose, for instance, the results of this study are used for that purpose. One may look at the combined frequency scores (see Table 2) and conclude that increased familiarity with information sources will increase their accessibility. A common way to increase familiarity with information sources is to conduct workshops to train engineers in using databases of all sorts, making them more familiar with these sources. Indeed, this approach has been recommended and used by libraries for decades. According to the results of this study, however, this is likely to have but a small effect.

On the other hand, helping engineers to become familiar with people who might be sources of information is of prime importance. This has been generally neglected by both research and practice in information science. Based on their case studies, Hertzum and Pejtersen (2000) recommended that companies establish services that are dedicated to searching for people. They envisioned an expanded company directory that included not only information about each person such as professional background, experience and responsibilities, but also about the relationships between an engineer and a person in the directory. One can imagine, for example, that each engineer has his own version of the directory. Entries for each person might include facts such as how busy he found that person to be, or when the engineer gave information to that person, which would help the engineer decide if he could ask for information in return.

Building a directory, however, is not the only method for developing and sustaining familiarity among engineers. While not traditionally considered by designers of information systems and services, creating services to support and expand personal networks may be a promising direction to increase familiarity as well. Building and maintaining these networks requires engineers to invest time and effort (Nardi, Whittaker, & Schwarz, 2000). Providing infrastructure, conditions, and motivation for engineers to create and maintain large, rich, personal networks will increase the number of people an engineer knows inside and outside of the organization. This, in turn, will enlarge the group of human information sources to which the engineer can turn. Our knowledge of communication among engineers, however, is insufficient to inform the design of services that improve the accessibility of human information sources. As Hertzum and Pejtersen (2000) pointed out, much detailed empirical research is needed before we can design systems and services for improved accessibility of human sources.

6.3. The need for detailed empirical research

How to conduct such research is an issue that requires attention as well. While mass questionnaire distributions revealed the importance of source accessibility, new approaches are necessary now if we want to improve the effectiveness of information seeking for engineers. The methods used in most previous studies have three major limitations. First, because they aimed to measure a number of variables, researchers had to assume that concepts loaded with meanings such as *accessibility, availability* and *ease of use* were clear and unambiguous. Second, most studies solicited responses only about engineers' perceptions of the *importance* of each concept, and neglected asking about their perception of the *frequency* in which they needed to employ these concepts. Third, researchers asked engineers to express their perceptions, but used no measures to find out how frequently these perceptions *actually* played a role in the engineers' everyday work. Thus, the results reflect what engineers *think* is most important but not what engineers actually *do*.

This may explain the discrepancy between the findings of this study and those of previous studies. To find out the factors used when selecting information sources, we asked engineers to describe in great detail a number of cases in which they looked for information that occurred in the preceding 24 hours. For each case, they explained why they chose a particular source. When describing these cases, engineers did not need to reflect and identify general patterns in their information seeking behavior; they simply reported what went through their minds. To answer general questions about their typical behavior, queries which are common in questionnaires, engineers have to observe their own behavior, analyze it and identify general characteristics. While some people pursue such analyses as a matter of course, many others just go about their work without reflection and analysis. It is not clear how much analysis they actually perform when they answer questions in a questionnaire or an interview. As a result, recommendations that come out of such studies may not be highly effective for improving information systems and services.

The most promising studies about accessibility are those that take into consideration the multifaceted context in which engineers work. Because they consider the work context, such studies would not be generalizable immediately. Their results, however, would be highly relevant to the engineers working in that context. Further, such studies should investigate both the engineers' perceptions and the ways in which they actually select information sources. Applying this new approach to research will make it possible to utilize results from research projects to improve information systems and services. It will also make it possible to identify similarities and differences within and across contexts. This will allow generalizations about the information seeking behavior of engineers that are likely to be effective for the design of information systems and services.

7. Conclusions

The information seeking behavior of engineers is a complex phenomenon. Engineers' work is complex and so are the organizations in which they most often work. Nevertheless, much of the previous research about the accessibility of information sources discounted this complexity. The study described here illustrates that the factors engineers used for selecting information sources were complex as well. The study showed that the concept of *accessibility* can be construed in many different ways. In fact, the ambiguity and disparity of meanings render the concept meaningless if one uses *accessibility* as the basis for attempts to improve information systems and services.

Previous research has established that engineers aim at minimizing effort when they seek information. This fact by itself, however, is not sufficient for the design of information systems and services. To help engineers minimize their effort, it is necessary to understand the various types of effort they want to minimize and how to make it possible for them to do so. Therefore, to successfully enhance engineers' information seeking, one needs to examine the specific factors that motivate an engineer to prefer one source over another. The results reported here provide a small step in that direction. Although derived from engineers' accounts of cases in which they looked for information, a number of the questions raised in the study require further investigation. Responses are needed to questions such as: How can an engineer's time be saved when looking for a documentary or human source; When is an information source considered interactive; and, How do engineers define "levels of detail"?

Similar studies in other contexts will enrich our knowledge of the factors that influence an engineer's decisions about selecting information sources. Although only the first step, this study demonstrates that detailed, open-ended interviews with engineers are a promising approach to uncovering their perceptions. An in-depth understanding of engineers' thoughts and the context in which they work is likely to support interpretations of data that can be successfully employed in the design of information systems and services.

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