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ARE WE IGNORING OUR OWN?

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"There is something still worse, however, than being either criticized or dismantled by careless readers: ***it is being ignored****. Since the status of a claim depends on later users' insertions, what if there are no later users whatsoever? This is the point that people who never come close to the fabrication of science have the greatest difficulty in grasping. They imagine that all scientific articles are equal and arrayed in lines like soldiers, to be carefully inspected one by one. However, most papers are never read at all. No matter what a paper did to the former literature, if no one else does anything with it, then it is as if it never existed at all"* (Latour, 1987).

ABSTRACT

The publication rates of earthquake engineering researchers and academics are essentially the same as the average publication rates of science and engineering professors in the United States. Yet, in 2004, of the 212 of the "world's most cited and influential researchers" in the category of *engineering*, listed by HighlyCited.com, none was an earthquake engineer. In terms of an approximate metric used in this paper, the citation threshold for researchers in the related fields of mechanics and finite elements on the HiglyCited.com list is about 6,000 total (not corrected) citations. At present, the most cited earthquake engineers have about half that many citations. Apparently, the absence of earthquake engineers on the HighlyCited.com list for *engineering* is largely a consequence of the small number of references in engineering papers and books.

Keywords: *Publication rates; scientific citations; earthquake engineering.*

1. INTRODUCTION

During the last decade, we have witnessed a phenomenal growth of electronic forms of information processing, archiving, and dissemination. An increasing number of journals are now published and distributed electronically, before the hard copies reach the libraries. Because of this, plus the shortage of space and the high cost of printed material, many research libraries subscribe only to the electronic versions. Concurrent with these trends has been the growth and widespread use of different "search engines" through abstracts of published work, which often provide a quick access to an electronic file of the publication. To facilitate this process, many organizations now specialize in a comprehensive information dissemination, which often includes comprehensive analyses and summaries of scholastic output and performance, in general. The Garfield's Information Science Institute* (ISI, now part of Thomson Corp.) in Philadelphia, for example, which publishes the Science Citations Index Expanded, also provides a broad spectrum of information services, including access to the full text of many papers published electronically, summaries of cited and citing references, and various analyses of the associated trends. Every year, USNews.com publishes a ranking of the top 100 to 150 American universities. They also publish rankings of departments, based on peer reviews. ISI has recently entered this arena by ranking departments according to the number of citations of the papers published by their faculty (http://www.in-cites.com/research/2003/december_1_2003-1.html).

Up to the early 1970s, earthquake engineers could publish only in several journals, and their papers were accessible only to those who could use the libraries in the leading educational and research institutions worldwide. The editors of these journals played a significant role in influencing the emphases and scope of the papers accepted for publication. Starting in mid 1970s, many new journals and a multitude of conferences gradually emerged, increasing the choices of researchers where to publish. The libraries, faced with space and funding limitations, had to select and eliminate "insignificant" journals in a rational way. Their difficulties created a fertile environment for the acceptance and popularity of the ISI's journal impact factors (JIF, Amin and Mabe, 2000). The appearance of JIFs put pressure on journal editors and editorial boards to increase the journal's JIF rating or otherwise face extinction. At present, ISI includes only about 6,000 in their list of "leading journals" worldwide, and the presence of a journal in this list, determined by the threshold value of JIF, is becoming a *conditio sine qua non for recognition*.

Originally developed for use by libraries, JIF gradually became popular in many other analyses of research production, including those related to evaluation of the quality of faculty publications. At present, at an increasing number of institutions, JIFs are used to evaluate the potential significance of publications (Garfield, 2003), and are becoming common in the preparation and analysis of promotion files (Frank, 2003). A high JIF implies a better chance for quality (via citation popularity of a journal where the work is published), but it cannot and should not be used to imply that the work is an important contribution to science, that it will be cited, or that it is indeed of high quality. The relative significance of a journal paper will be reflected eventually in terms of the citations it receives. The impact of authors is now also being assessed in terms of the number of citations their papers receive over time.

Recently, HighlyCited.com (Thomson/ISI) has started to collect data on the "world's most cited and influential researchers." In May 2004, HighlyCited.com had 212 individual researchers in the category of *engineering* worldwide. Of those, 152 work in the United States where they are distributed among 49 universities (79%) and 19 government laboratories or private corporations (21%). However, none of the 212 researchers on the list are from the

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* Dr. Eugene Garfield is ISI's founder and chairman emeritus. He is the editor of Science Citation Index, Journal Citation Reports—a bibliometric analysis of science journals in the ISI database, by the Institute for Scientific Information (ISI, http://www.isinet.com/), 3501 Market Street, Philadelphia, PA 19104, USA). Many of Garfield's writings have been posted on his Web site at http://www.garfield.library.upenn.edu. Since 1992, ISI has been a Thomson Scientific Company and part of The Thomson Corporation (http://www.thomson.com), which provides Web-based information for researchers, information specialists, and administrators. More information about ISI is available at http://www.isinet.com/ISI.

field of earthquake engineering. Possible causes are, for example, (1) lower publication rates, (2) smaller number of journals included in the ISI database, and (3) lower citation rates compared to the other fields of engineering, as well as (4) too restrictive time window used by HighlyCited.com (1981 to 1999), and so on. These four and other possible causes need to be studied before we can begin to understand the above outcome. Trifunac (2005a) examined the first possible reason and showed that the average publication rates in earthquake engineering are very close to the U.S. national average trends in engineering and the sciences. Thus, other aspects of the published work in earthquake engineering have to be analyzed to explain why there are no earthquake engineers on the ISI's highly cited list of "influential researchers" in engineering.

The citation threshold for researchers in the related fields of mechanics and finite elements who are on the HiglyCited.com list for engineering is about 6,000. The most cited earthquake engineers in a sample of 51 studied by Trifunac (2005b) have about half that many citations in the ISI database. This suggests that the reason why there are no earthquake engineers on the HighlyCited.com list for engineering is somehow related to the facts that nearly 80% of journal papers in civil engineering are not cited within five years after publication, that the cohort of earthquake engineering researchers is very small relative to those for other engineering disciplines, and that earthquake engineers do not cite the work in their field at a rate that is comparable to the rates in other engineering disciplines.

2. CITATION RATES

In the early 1990s, ISI analysis showed that 55% of the papers published in journals covered by ISI are not cited within five years after publication (Hamilton, 1991a). Grouping into broad categories showed that articles in physics and chemistry were most cited, or had the lowest rates of uncitedness—37% and 39%, respectively. Those were followed by the biological sciences (41%), the geosciences (44%), and medicine (46%). These subjects all fell below the uncitedness average of 47% for the "hard sciences" (disciplines including basic sciences and medicine but excluding the social sciences). The figure for engineering, however, was well above the average in uncitedness. More than 72% of all papers published in engineering were not citated. Within the above broad categories, there is a wide variation among individual sub-disciplines, as illustrated in Fig.1. It can be seen that all the engineering fields exhibit a high rate of uncitedness, with civil engineering being the highest, at 78%. Next came mechanical (77%), aerospace (77%), electrical (66%), chemical (66%), and biomedical (60%). Other applied fields had similarly high rates of uncitedness: construction and building technology (84%), energy and fuels (80%), applied chemistry (78%), materials science—paper and wood (78%), metallurgy and mining (75%), and materials science—ceramics (73%).

Even papers that do get cited are not cited very often. An ISI study of articles in the hard sciences published between 1969 and 1981 showed that only 42% were cited more than once (Hamilton, 1991b). When asked whether this means that more than one half, of the scientific literature is essentially worthless, some 20 academicians, federal officials, and science policy analysts concluded "researchers are publishing far too many inconsequential papers in order to pad their resumes" (Hamilton, 1991b).

Figure 2 illustrates the percentages of cited contributions of 12 faculty members in the Civil Engineering Department of the University of Southern California (USC). It shows the total rates and separately the rates for journal papers, reports, and conference papers (Trifunac and

Lee, 2004). Collectively, these rates are higher than the national average of 28% for civil engineering (Hamilton, 1991b), but they are spread over a considerable range, indicating the need to consider their dependence within more homogeneous subgroups of different specialties.

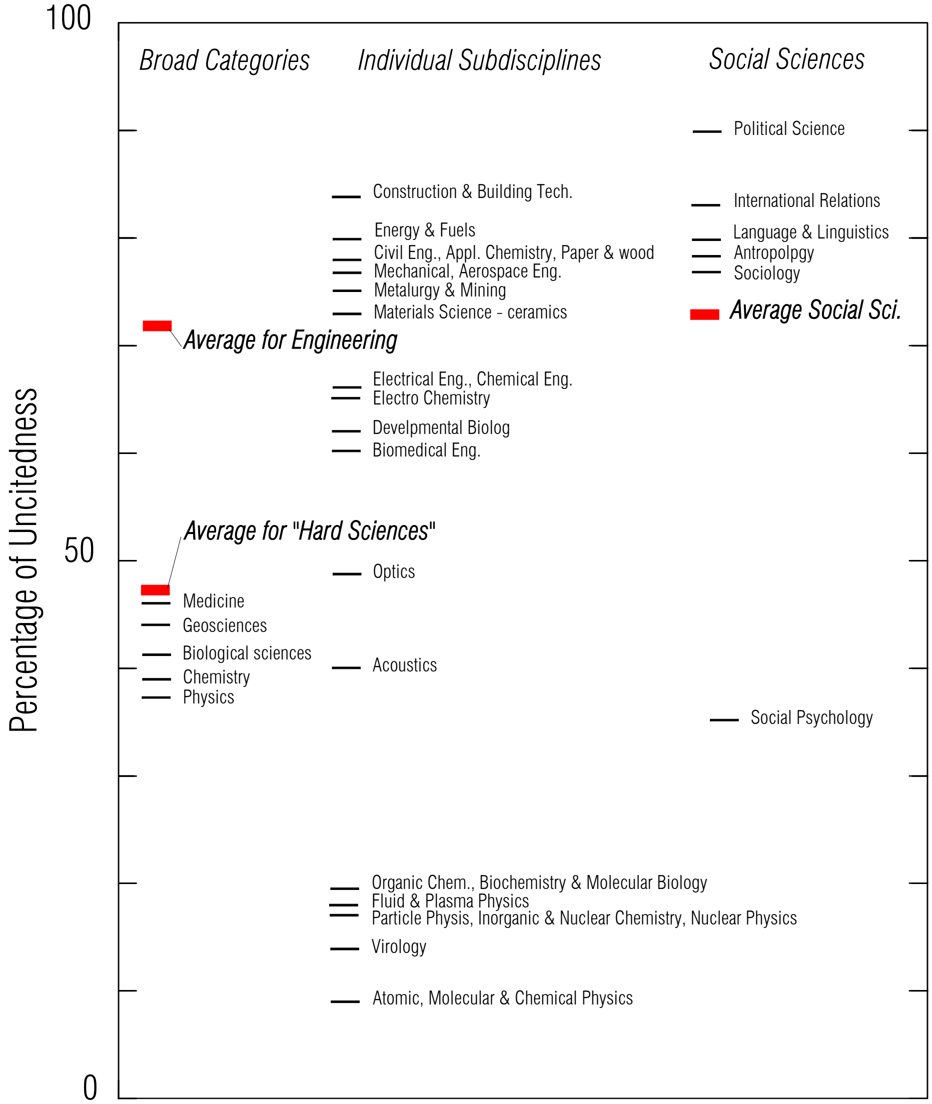

Fig. 1. Variations in uncitedness among individual disciplines and sub-disciplines.

3. JOURNAL IMPACT FACTORS

The journal impact factor is calculated by dividing the number of current citations a journal receives for articles published in the two previous years by the number of articles published in those same years. For example, the JIF for 1999 is the number of citations received in 1999 for articles published in 1997 and 1998, divided by the number of articles published in 1997 and 1998. The values of JIFs are affected by the subject area of the journal, the type of journal (letters, full papers, and reviews), the average number of authors per paper, the size of the journal, and the duration of the citation measurement window.

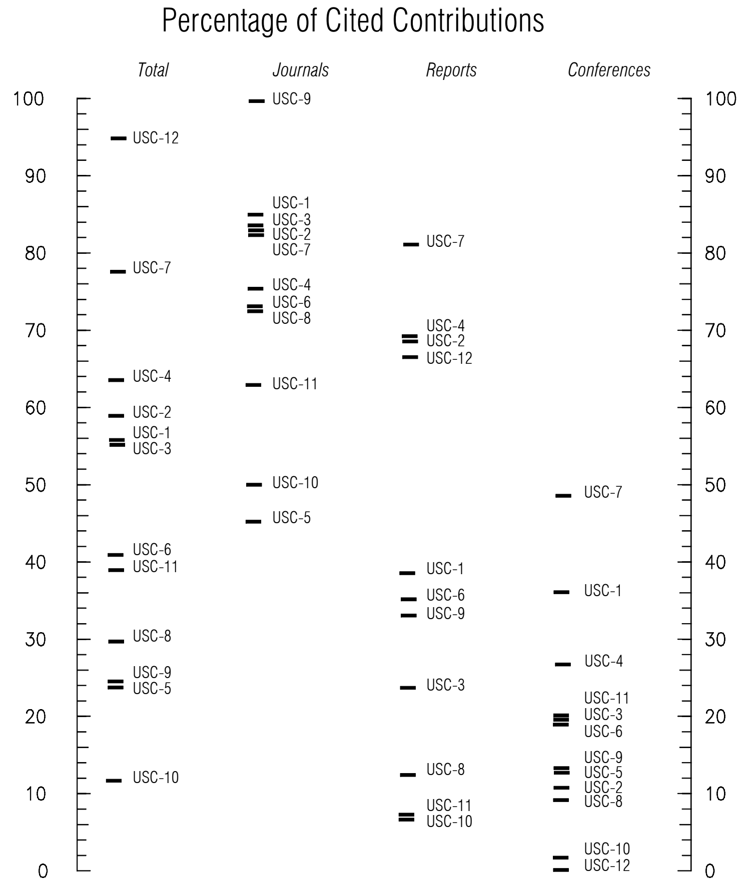

Fig. 2. Percentage of published articles cited at least once for a sample of twelve faculty in Civil Engineering at USC, listed for all publications (total), and separately for journals, reports, and conference papers.

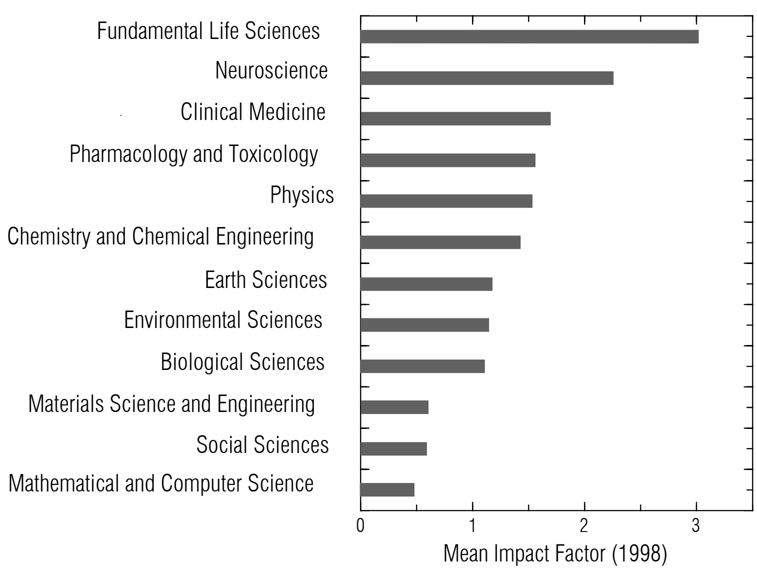

Fig. 3. Variations among Field Journal Impact Factors, for twelve subject fields.

Figure 3 illustrates the variations in JIF based on the subject field. Fundamental subject areas usually have higher average impact factors than specialized and applied subjects, and the variation is very significant. A top journal in the field may have an impact factor lower than the bottom journal in another field. For 1998, for example, the mean JIF in materials science and engineering was about 0.6, while for environmental sciences it was about 1.2 (Trifunac and Lee, 2004).

The impact factor is an average value, and therefore is subject to variations caused by the number of items being averaged (that is, the number of articles published in one year) and the measurement window, usually taken to be two years. ISI defines JIF in terms of a two-year window (a one-year citing window and a two-year cited window). When a large number of journal impact factors are analyzed from one year to another against the size of the journal, there is clear correlation between the fluctuations of JIF and the size of the journal. Small journals, with less than 35 papers per year on the average, have impact factors that vary by up to 40%. Journals with 150 articles per year have fluctuations of JIF of about 15%. Figure 4 illustrates fluctuations of JIF versus time for selected journals that cover earthquake engineering. Table 1 shows the average impact factors for 6 fields, representing 55 disciplines, and based on 5,762 journals, presented for a 24-year window (1974–1998) (see Appendix B in Trifunac and Lee, 2004). For this period, the average Field Impact Factors (FIF) of 1,210 journals that publish in subject areas classified as "Engineering" is 0.57.

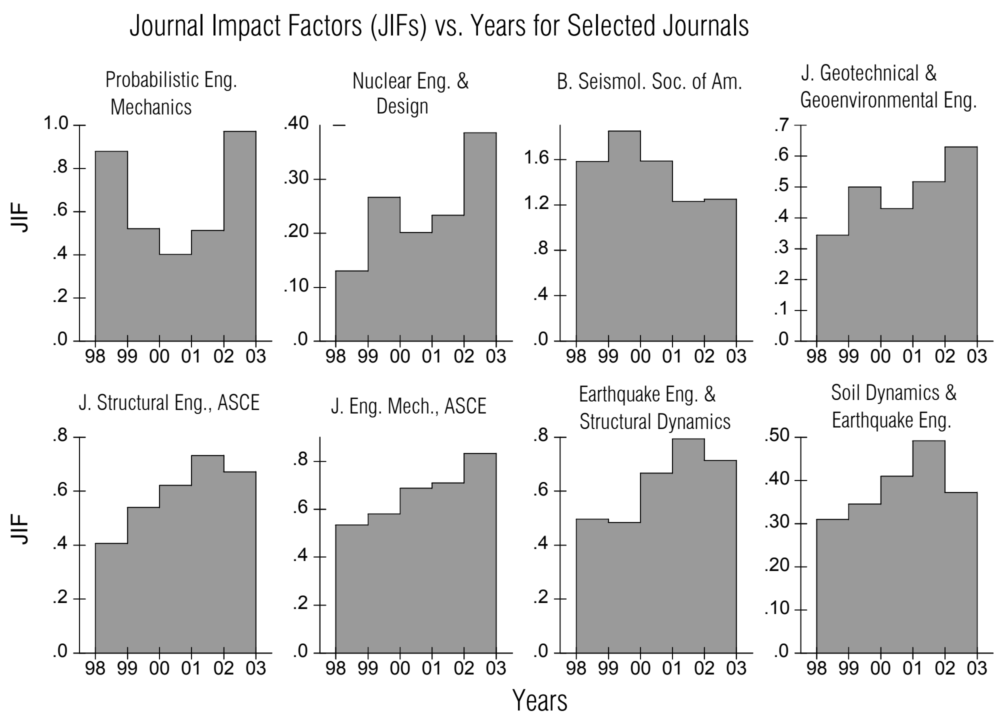

Fig. 4. Yearly fluctuations in JIF for selected journals that publish earthquake engineering papers.

Figure 5 (bottom) shows a histogram of the distribution of JIF for 1,210 journals in engineering, in the range between 0 and 2. The top part shows the corresponding distribution function. The JIF for the three journals that did in the past (Bull. Seism. Soc. of Am.), and still publish today many earthquake engineering papers are shown. An additional 35 journals with high JIFs, in the range between 2.0 and 9.0 (Geol. Survey Prof. Papers), are not shown in this figure.

Table 1. Field impact factors

FIELD	N	%	FIF
BIO	2,469	43	1.43
CHEM	551	9	1.34
ENG	**1,210**	**21**	**0.57**
MATH	671	12	0.46
PHYS	687	12	1.28
SCI	175	3	0.87
	SUM = 5762	**100**	**AVERAGE=1.11**

(N= Number of Journals in the Field, FIF= Average Field Journal Impact Factor)

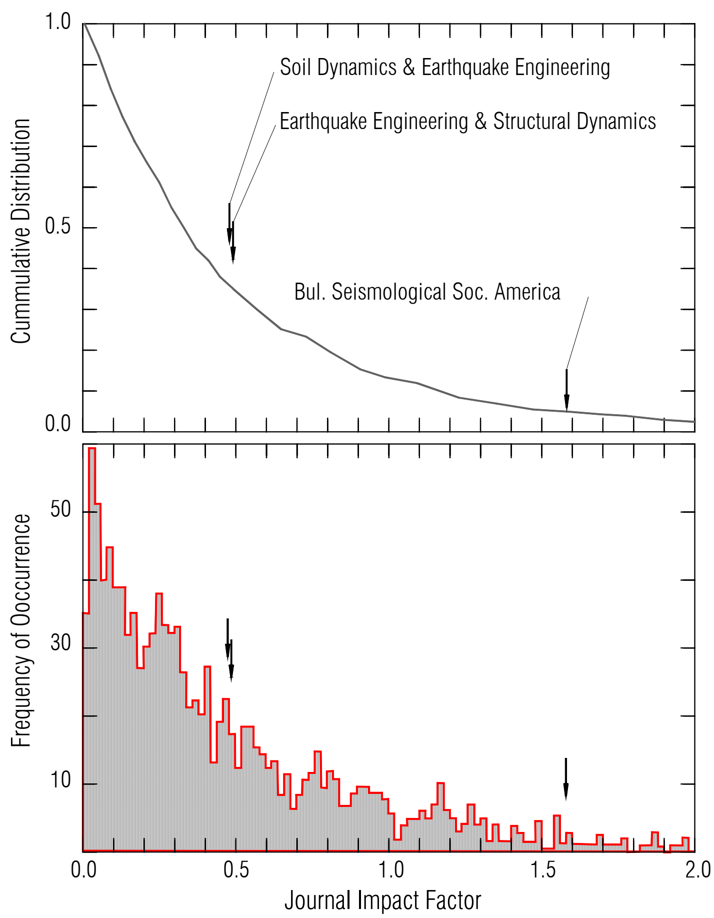

Fig. 5. Histogram (bottom) and distribution function (top) of Journal Impact Factors (JIF) for 1,210 Engineering Journals. The JIF for three journals, which published (BSSA) and publish at present (SDEE, EESD) earthquake engineering articles are shown.

As can be expected, the mean impact factors in different fields (FIF) are correlated with the percentage of cited papers in those same fields. This is illustrated in Fig. 6 for eight fields by combining the data shown in Figures 1 and 3. It is seen that the social sciences and engineering have low FIFs and percentages of cited papers.

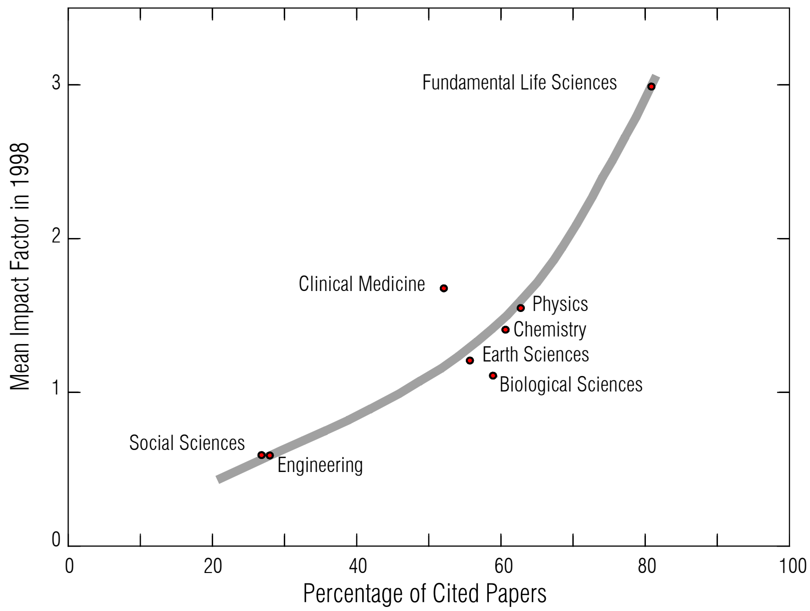

Fig. 6. Correlation between percentage of cited papers and the mean field impact factors.

4. PUBLICATION AND CITATION RATES IN EARTHQUAKE ENGINEERING

In his analysis of publication rates, Trifunac (2005a) considered a sample of 57 faculty and used the Earthquake Engineering Abstracts (EEA) database covering earthquake engineering and the related fields—structural and geotechnical engineering, applied mechanics, engineering seismology, and engineering geology. At present, the EEA database has more than 100,000 abstracts and can serve as a quantitative measure of who the active contributors in this field are. This database was accessible free of charge until January 2004, when it became part of Cambridge Scientific Abstracts (CSA), a privately owned information management company located in Bethesda, Maryland, that publishes abstracts and indices for scientific and technical research literature (http://www.csa.com). To quantify publication productivity of earthquake engineers, Trifunac (2005a) assumed that the number of publications for each author could be approximated by the number of their contributions recorded in the EEA database. He showed, through a detailed analysis of the data for 10 faculty, that this is a reasonable approximation. The sample of 57 faculty is neither comprehensive (aiming to cover all areas of earthquake engineering) nor balanced (e.g., geographically, by seniority, by gender, etc.). It includes many past and present leading professors in earthquake engineering. From among the 57 faculty, 3 (5%) are deceased, 14 (24%) are retired, 37 (65%) are full professors, 1 (2%) is an associate professor, 1 (2%) is an assistant professor, and 1 (2%) is a research professor. This is equivalent to 40 (71%) "active" faculty and 17 (29%) retired or deceased faculty. Overall, 54 (94%) of this sample are "senior" professors, mostly working in civil engineering departments in the United States. Of the 57, 56 are male and 1 is female.

To maintain confidentiality, the faculty names have been replaced by an abbreviated code representing the institutions where they work, followed by a randomly chosen number (Trifunac, 2005a). Figure 7 illustrates, for a subset of 18 faculty, the cumulative number of abstracts in the NISEE database, versus time, measured since the publication of the first abstracts (approximately equal to years since Ph.D.). The highest publication rate for this sample is 302/37.5 = 8.05 per year (USC – 7), and the lowest is 99/50 = 1.98 per year (CIT – 1).

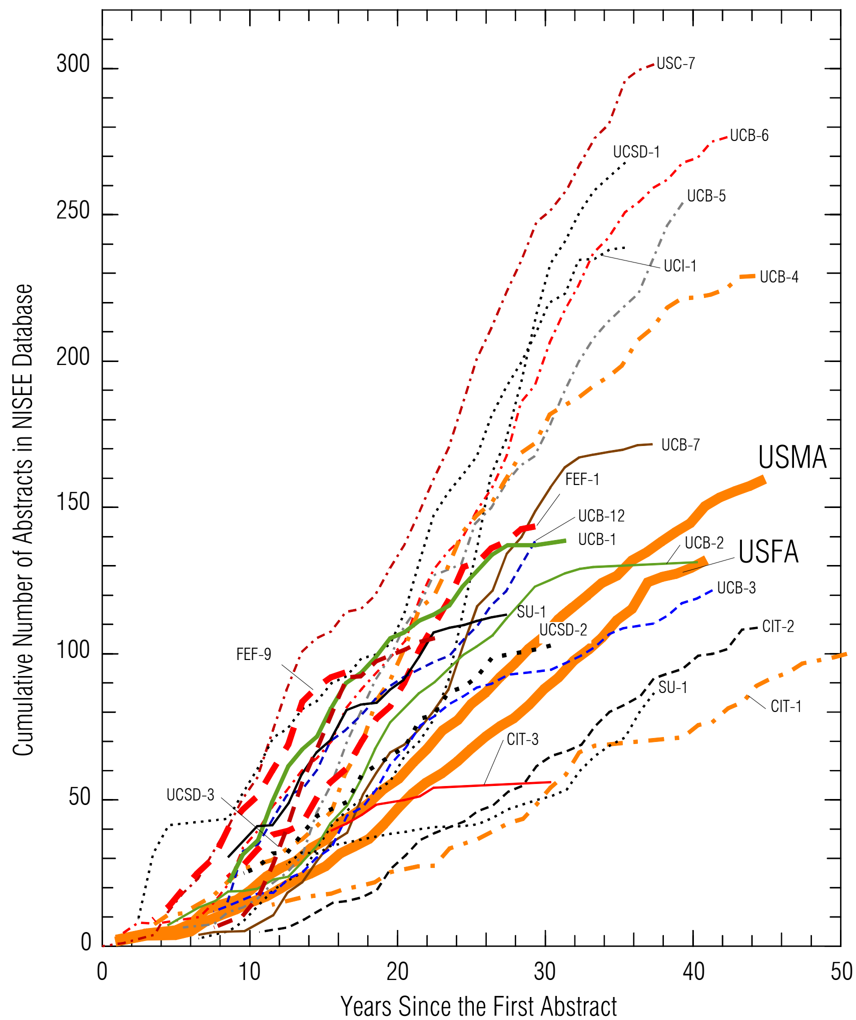

Fig. 7. Cumulative number of abstracts (journal papers, reports, and conference papers) versus number of years since publication of the first reported abstract, for 18 faculty in earthquake engineering. Mean cumulative number of publications in science and engineering also shown for male (USMA) and female (USFA) faculty at American universities.

To evaluate the publication rates in earthquake engineering Trifunac (2005a) integrated the mean publication rates among university professors for the period between 1960 and 2000, as reported by Bozeman and Lee (2003), and computed the cumulative number of papers for male faculty "USMA" (United States male average). The average slope of the USMA curve

(Fig. 7) is about $\overline{x}_{\mathrm{USMA}} = 3.57$ papers per year, essentially same as the $\overline{x}_{\mathrm{total}} = 3.34$ average for the sample of 57 earthquake engineers. For completeness of this presentation, the cumulative curve "USFA" (United States female average; see Trifunac, 2005c) is shown as well.

The citation rates of journal papers depend upon numerous factors, some of which are the general subject area (e.g., Fig. 3), the type of paper (letter, full paper, review), number of co-authors (e.g., see Appendix A, in Trifunac and Lee, 2004), number of self-citations, personal style, time window, and many others. Here we illustrate only one such simple and direct dependence, which is related to the productivity rate of the authors. Figure 8 illustrates the simple correlation of y = total number of citations per author with x = total number of journal papers per author, both plotted on a logarithmic scale, for a group of 12 USC faculty in Civil Engineering. The average trend is y = 0.4 + 1.275x, where y = log (number of citations per author) and x = log (number of journal papers per author).

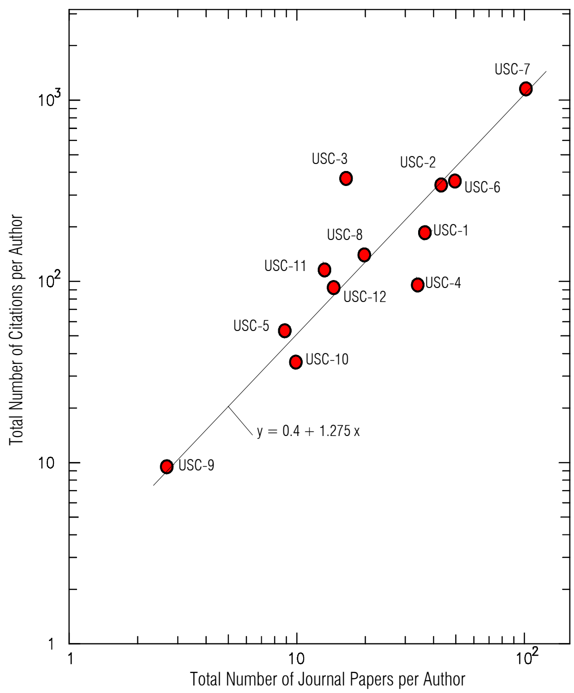

Fig. 8. Correlation between number of citations per author and number of published papers per author.

Figure 9, shows the total number of ISI citations (y) versus the total number of NISEE abstracts (or equivalent) (x), both plotted on a logarithmic scale for a sample of 51 faculty studied by Trifunac (2005b). With few exceptions, most data points fall between 1 and 50 citations per NISEE abstract. With respect to this sample, it can be seen that Biot, UCB-1, UCI-1, and USC-7 are among the top 5%.

As in Figure 7, to maintain confidentiality, the faculty have been assigned code names that consist of an abbreviated code for the institution at which they work, followed by a number. The one exception is Maurice A. Biot (1905-1985), the father of modern earthquake engineering (Trifunac, 2003; 2005d). His unique position in the plots can serve as a benchmark of excellence.

The gray zone in Figure 9 shows the range beyond about 6,000 total uncorrected citations. It represents our estimate of the current threshold of total citations required for inclusion in the list by HiglyCited.com of the leading researchers in the world in the category for *engineering* (Trifunac 2005b). At present, the most cited earthquake engineers in our sample (UCB-1, UCI-1, and USC-7) have about half that many citations.

5. ANALYSIS AND DISCUSSION

The forgoing summaries of the publication and citation rates in earthquake engineering suggest that the most likely reasons for the absence of earthquake engineers on the HiglyCited.com list for engineering is the low overall rate of citations of earthquake engineering papers.

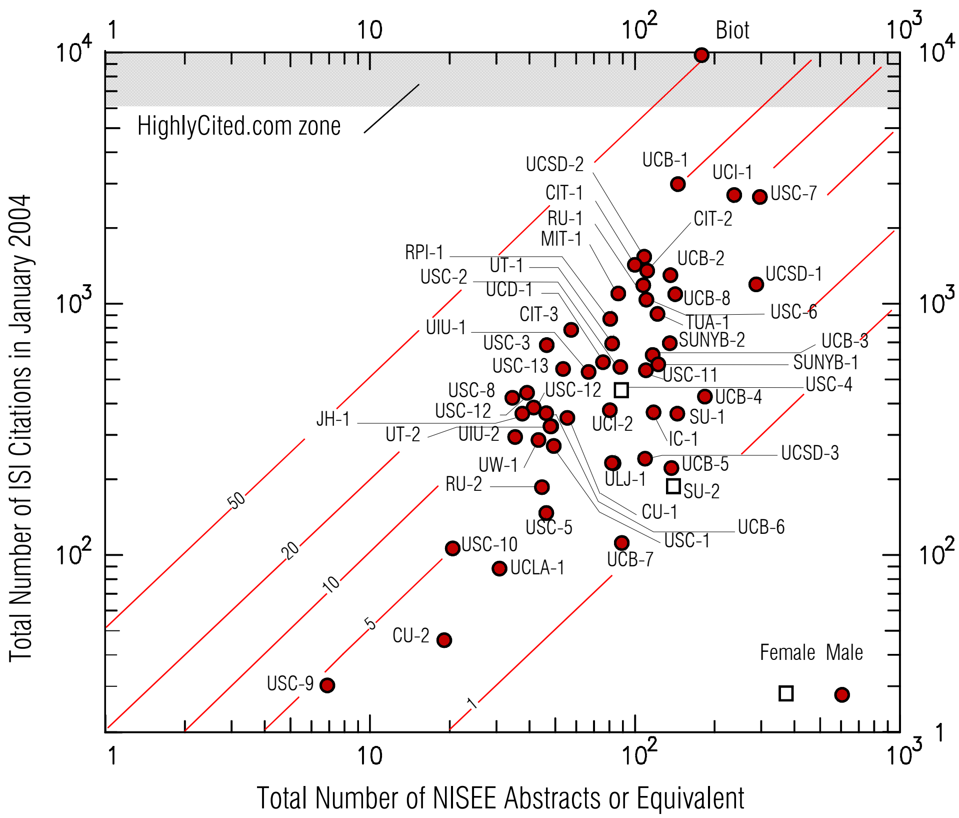

Fig. 9. Total number of ISI citations (as of January 2004) versus the total number of NISEE abstracts or equivalent, for a sample of earthquake engineering researchers. The gray zone shows the approximate range for individuals on the HiglyCited.com list for engineering.

Assuming that all "engineering" journals have the same JIFs, that there are effectively about five of 1,210 journals (see Table 1) that publish only earthquake engineering papers, and that 212 members in the HiglyCited.com list for *engineering* are selected by independent random draws, would suggest that the expected number of earthquake engineers in the list would be 212(5)/1,210=0.87. The group of "engineering" journals with the distribution of JIF shown in Fig. 5 includes geological, seismological, and geophysical journals, which have two to three times higher citation rates than the earthquake engineering journals. This bias in citation rates would further reduce our estimate of 0.87 by a factor of three or more, perhaps to the range of

0.2 to 0.3. Thus it is not surprising that there are no earthquake engineers in the HihlyCited.com list. In the following we explore other examples, which further show a relatively small number of references in earthquake engineering papers.

Figure 10 compares the number of references per page in ten earthquake engineering books, with three seismological and one engineering mechanics (Bazant and Cedolin, 1991) books. Our sample is small, but the trend does not contradict what is implied in Figure 5. In this example, the number of references per page is 0.5, 1.2, and 1.8 respectively for earthquake engineering, seismology, and engineering mechanics. The corresponding factors are 2.4 and 3.6 relative to earthquake engineering.

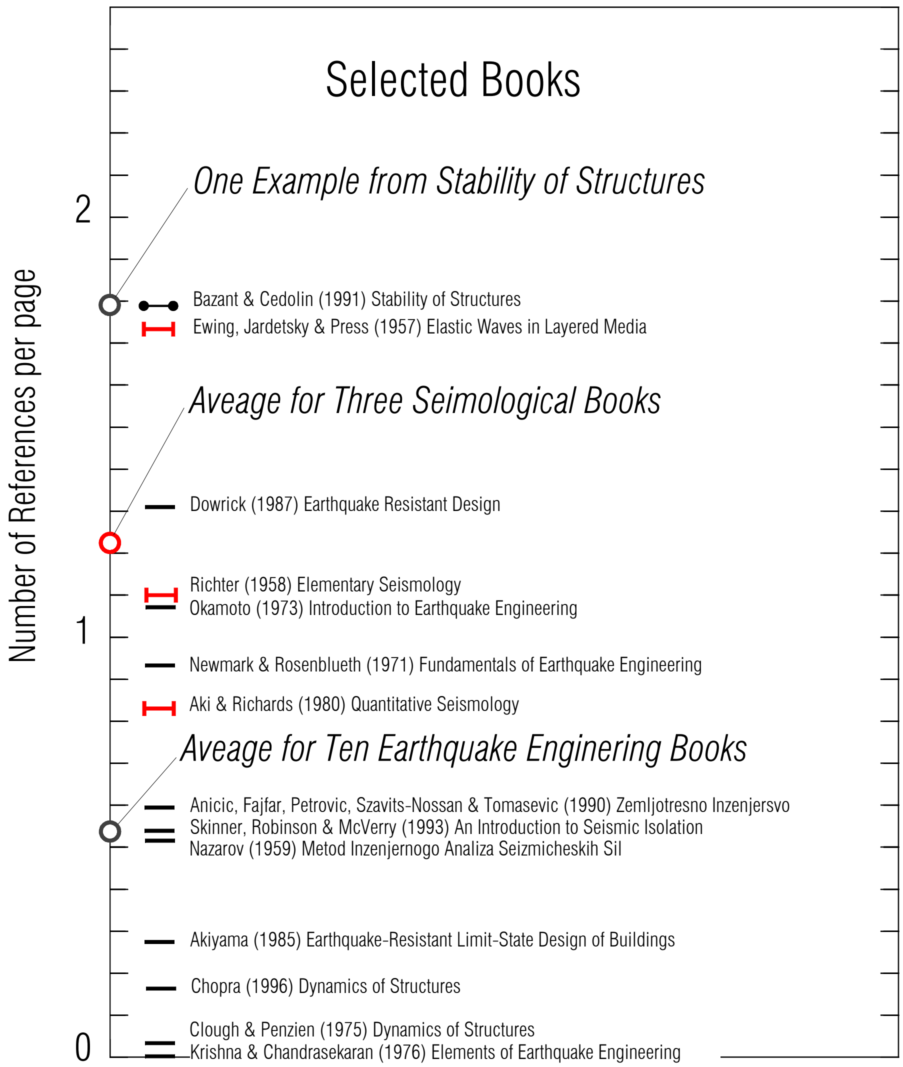

Fig. 10. Examples of the distribution of the number of references per page among ten earthquake engineering, three seismological, and one structural mechanics books.

Earthquake Engineering, a book edited by Wiegel (1970), is a collection of chapters written by several earthquake engineers, a seismologist, and a geologist during the late 1960s. Figure 11 shows the number of references per page for the authors who contributed individual chapters to this book (left), the overall average (about 2), and the averages for different subject areas covered by the book (right). It shows higher rates of referencing in geological and seismological writings than in earthquake engineering, by a factor approaching 4. We did not include this book in the sample presented in Figure 10, because it is essentially a collection of independent review papers, while the books included in Fig. 10 are classical, single, or multiple-author books.

The above examples ignore the time factor, which is not negligible. During the period between about 1960 and 1995 there occurred a rapid increase in publication rates. This period is often called the *publish or perish* era (Bozeman and Lee, 2003). During this time, the mean number of papers (normal and per-author counts), published per year by engineering and science professors working in the United States grew from about 0.1 to 3.5 (Fig. 12). Since the authors in earthquake engineering who wrote during 1940s and 1950s had a much smaller number of papers and books at their disposal, it is to be expected that this would be reflected in the number of references in their papers. Figure 12 illustrates this by an example, comparing the mean number of publications for engineering and science professors between 1960 and 2000 (left scale), with the average number of references per page for three professors of earthquake engineering (right scale), for time windows in their careers for which coherent data are readily available (1933-1973, 1941-1987, and 1967-present). These windows are centered near 1953, 1964, and 1983. It is seen that the correlation of the two trends is good. Since the rates of referencing in other areas of engineering may have experienced similar changes, this time dependence does not contradict the above examples, showing that the citing rates by earthquake engineers have been and continue to be low.

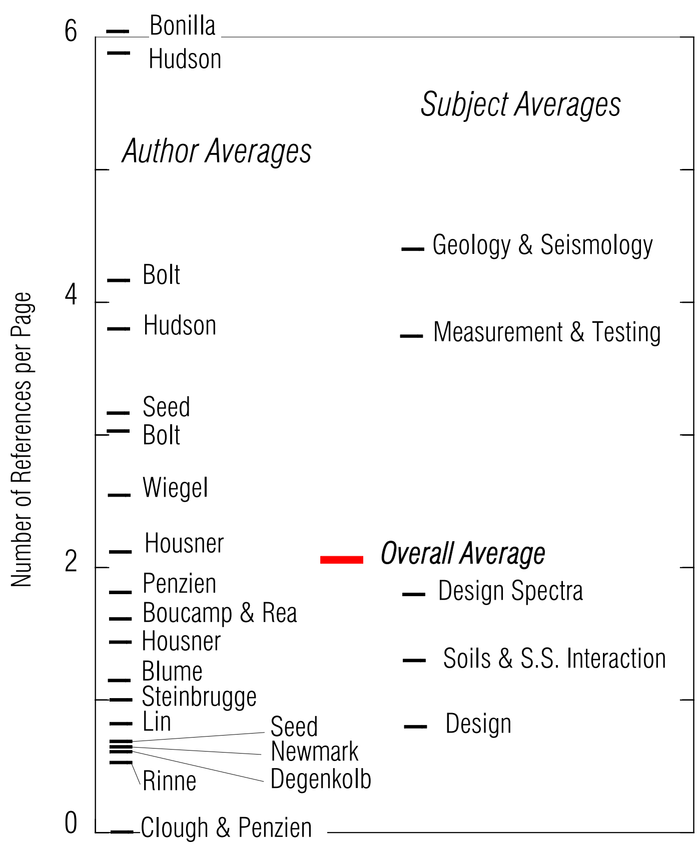

Fig. 11. Distribution of the number of references per chapter page among the 19 chapters of the 1970 *Earthquake Engineering* book edited by Wiegel.

The sample sizes presented here are small, and hence the trends they indicate cannot be considered statistically significant. Yet, these examples all suggest that the citing rates in earthquake engineering are indeed low. Since it is just a matter of time before other, more detailed analyses of the type exemplified here become available that complement the HighlyCited.com lists, it is clear that it is useful and timely for earthquake engineers to study and to understand the possible consequences of such analyses.

In this context, one cannot but question the wisdom of the authors who write books, intended for use in earthquake engineering courses that are essentially without references. Their justifications vary from explicit - "it is impractical to acknowledge sources for information presented....to avoid distracting the reader," or "most such contributions are so well established in the field of structural dynamics that it is difficult to assign credit for them. Consequently, few credit sources are given…" - to no comments at all. One can wonder how many undergraduate and graduate students in earthquake engineering, at the time they take their first class in structural dynamics, know about the "well established contributions to the field." The professors are the role models for many of those students and can leave profound and lasting impressions, guiding the modus operandi of future generations of professors and engineers. It is not surprising then that their students do not know, or by imitating their teachers do not cite, the fundamental sources of the governing ideas and the authors who first formulated the new and original methods.

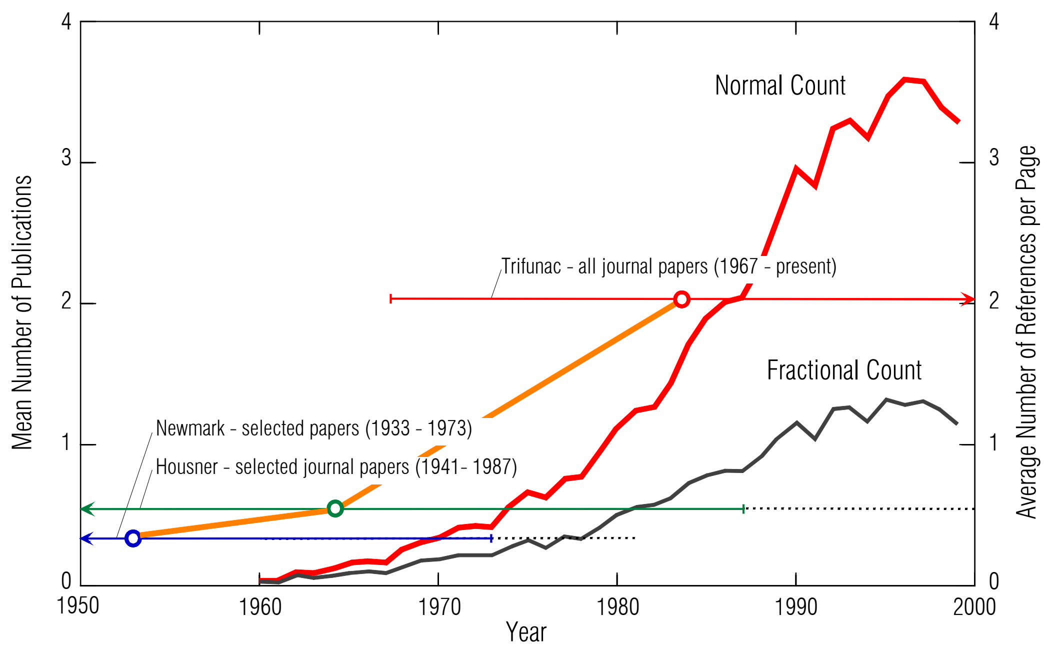

Fig. 12. Growth in time of the mean number of publications per year for American faculty in science and engineering (normal or total count and fractional or per-author counts), and the number of references per page for three earthquake engineering professors (Hall, 1976; Hudson, 1990; Trifunac and Lee, 2004).

Consider, for example, the contributions to earthquake engineering by Maurice A. Biot (Trifunac, 2003). In 1932, in his doctoral dissertation – he was a student of Theodore von Karman at Caltech - Biot developed a concept that he later extended into the complete formulation of the Response Spectrum Method (Biot, 1932, 1933, 1934, 1941, 1942). Today, 70 years later, it would be difficult to imagine any work in earthquake engineering that does not use the Response Spectrum Method. Biot taught at Caltech, Brown, and Columbia universities for about twenty years, before becoming an independent consultant in the early 1950s. Following his seminal contributions to earthquake engineering ("Earthquake engineering as such could be considered to have been born with Biot's concept of a response of an idealized structure to ground motion," Krishna, 1981), Biot made fundamental contributions to many other fields, including poroelasticity, folding, the theory of incremental deformations, oil exploration, and thermodynamics. Yet the number of citations Biot received from earthquake engineering authors between 1975 and present (the time covered by the ISI database) is very small (Trifunac, 2005d). For many years this could remain hidden, because there were no ISI data to help decipher the trends. Today, such data are readily available to all. It can help eradicate the culture of appearances and motivate new generations to use the data as a tool, to understand the evolution of modern methods, and to convert it into an instrument for self improvement and optimal selection of priorities for their own careers.

6. CONCLUSIONS

The scientific productivity of a sample of about 50 senior earthquake engineers is between 2 and 8 papers per year. The average for the group is 3.3 papers per year, essentially the same as the 3.6 papers per year, average productivity of science and engineering researchers in the U.S. For those papers, earthquake engineers receive a total between 3 and 100 citations per year, or between 2 and 20 citations per cited paper. In December 2003, the most cited members of our sample of earthquake engineers had about 3,000 total uncorrected citations.

In terms of the total uncorrected citations, it takes at least about 6,000 total citations for one to be selected by HighlyCited.com and included in the list of "most productive researchers" in *engineering*, and so at present this list includes no earthquake engineers. Analyses of the citation rates in engineering show that overall about 80 percent of all published papers in engineering journals never get cited, and almost half of those cited never get more than one citation. A detailed study of how many papers in earthquake engineering are never cited is beyond the scope of this paper, but the small sample of examples we presented confirm that the citation rates in earthquake engineering are lower than in seismology and geology. The conventional wisdom is that citations are the glue that bonds a research paper to the body of knowledge in a particular field and a measure of the paper's importance. Thus, a careful analysis of the ISI data can offer academics, university administrators, and government officials valuable material to reflect on. Citations are also a vehicle that places the journal paper into the historical framework of the field and shows how the ideas and methods evolve.

The small number of references in the papers that were published before the publish-or-perish era, resulted, in part, from lower publication rates before the 1960s. Today, with modern electronic information systems, a small number of references in earthquake engineering papers and books probably reflect lack of knowledge, hubris, or both. Those of us who teach earthquake engineering must try to change this trend because the innovation abilities of our students can grow through broad and multidisciplinary education that requires exposure to the history of many classical discoveries. Last, but not least, higher citation rates will bring about more visibility to earthquake engineering and deserved recognition for the many contributions our profession makes to society.

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