THE EFFECT OF PUBLICATION RATE PROFILE ON CITATION STATISTICS

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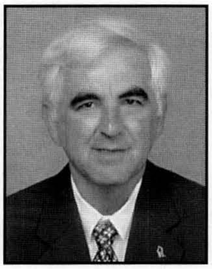
The application of citation statistics for evaluating and comparing research groups has continually increased in recent years. One reason for this trend is that such statistics are perceived to be quantitative and objective. In addition, the pertinent information is available through the Internet and the evaluation can be carried out with minimal expense.

Unfortunately, there are many pitfalls in using citation statistics as a sole measure of research achievements. Some of the pitfalls are mentioned, for example, by Grossman[1] and Angus, *et al.*[2] Those pitfalls can often lead to absurd results, as was recently shown in letters to the editor by Braun[3] and Reedijk.[4] The response from the institutes that provide the citation statistics and the citation analysts (Blazick,[5] van Raan[6]) state that citation analysis should be used only as an *additional*, supporting tool to peer review and should never be used in "isolation."

In the 1995 NRC report,[7] results of a research-related comparison study of 93 chemical engineering departments awarding PhDs in the US were reported. In that study, qualitative measures of research achievements (such as peer review) and quantitative measures, both intensive (such as the number of citations per paper, CPP) and extensive (*e.g.*, total number of publications and citations), were used. But even such an extensive and thorough study cannot be completely faultless (as was pointed out by Grossman[1] and Angus, *et al.*[2]) because of technical difficulties in collecting reliable citation data and the very different nature of the evaluated departments.

Furthermore, conducting both a thorough peer review and a quantitative evaluation can be time consuming and expensive. For this reason there is a growing tendency to rely on quantitative measures alone in evaluating and comparing research programs. Van Raan[6] has recently evaluated the validity of a measurement that he calls the "impact of the group." This measure is essentially the CPP divided by the CPP world average of the field (WAF). Studying various departments in The Netherlands, van Raan has found a strong correlation between quantitative measures, such as the CPP/WAF and results of the peer reviews. In spite of these positive results, he does not recommend the use of quantitative measures alone and calls for carrying out further research in cases where considerable differences are detected between results obtained by employing different measures.

In this paper the influence of the publication profile on the CPP is investigated. In the next section an example is pre-



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sented where the CPP and CPP/WAF yield results that are contradictory to the results of other measures of research impact and productivity. In the third section a simulation study of the influence of the publication profile on the CPP is presented and the weakness of the CPP is demonstrated. Finally, a new "weighted CPP," which is invariant of the publication profile, is introduced.

A MOTIVATING EXAMPLE

In a recent evaluation (carried out in January 2000) of the Chemical Engineering Department at the Ben-Gurion University of the Negev (BGU), an outside evaluation committee decided to use CPP/WAF as the only measure of research productivity and impact. As a basis for the evaluation methodology, the review produced by the Institute for Scientific Information (published in *Science Watch*[8] in 1992) was used. In this review, chemical engineering departments that had published more than a threshold value of 70 papers over the period of 1984-90 were ranked. The BGU department was ranked 24th in this list with 70 publications, 250 citations and 3.57 citations per paper. During the period of that study, there were twelve faculty members in the department, meaning 1.2 publications per year per faculty (P/Y/F)

The evaluation committee collected data from the Science Citation Index for the period of 1989-1999. Only citations of papers published starting in 1989 were considered. The study found that the total number of publications (cited at least once) during this period was 397; thus, 2.78 P/Y/F (11 years, 13 faculty). The total number of citations during that period was 1603; thus, 11.21 per year per faculty (C/Y/F). The CPP was obviously 1603/397 = 4.04.

According to the evaluation committee, the WAF for the same period for the field was 5.54, and thus the CPP for the BGU department was significantly below the world average. The committee based its conclusions regarding research productivity and impact of the department at BGU on the CPP/WAF alone, disregarding all the other available measures and relevant information.

In order to assess the validity of the CPP/WAF as a sole indicator in this case, we compared the P/Y/F and C/Y/F with similar figures obtained from the 1995 NRC report[7] (Appendix P, p. 500). The publication and citation data in the NRC report is for a period of five years (1988-1992). The corresponding values of the P/Y/F and C/Y/F for the departments included in this report indicate that there were fewer than ten departments in the US with values higher than 2.78 P/Y/F and 11.21 C/Y/F at the time of that study. Obviously, there are some significant differences between the study conducted by the NRC and the one conducted by the evaluation committee at BGU. Still, this comparison strongly implies that the CPP severely undervalues the research productivity and impact of the department at BGU.

The sharp increase in the publication rate between the periods of 1984-90 (1.2 P/Y/F) and 1989-99 (2.78 P/Y/F) at BGU provides a clue to the contradictory results obtained by using various indicators. The publication profile over the years may affect the CPP values and this could be the reason for the poor performance indicated by the CPP. This assumption is supported by the number of publications in peer-reviewed journals during the last five years, as provided by the faculty of the BGU chemical engineering department. The number of publications was 36 in 1995, 53 in 1996, 57 in 1997, 61 in 1998 and 85 in 1999—a sharply increasing profile indeed.

In order to check the effect of publication rate profile on the CPP, a simulation study has been carried out. The methodology used by the evaluation committee in the BGU (evaluation period, papers, and citations included, etc.) was used as the basis for the simulation model, as detailed in the next section.

THE EFFECT OF PUBLICATION RATE PROFILE ON CPP: A SIMULATION STUDY

The details of this simulation are shown in Table 1. The simulation covers the period from 1989-99. Only citations of papers published starting in 1989 are considered. Obviously, not all the papers have the same, constant citation rate. Also, the CPP can change with time, with a maximum around the 5th year after publication (Grossman[11]). In order to isolate the impact of the publication rate profile on the CPP, however, a constant citation rate of one citation per paper per year, starting one year after the year of publication, is assumed in all cases studied here.

Six different cases are considered. In the first case of "stop publishing," one paper was published in 1989 and none thereafter. In the second case of "slope: -2," ten papers were published in 1989 and thereafter the number of papers has been reduced by two every year, reaching zero publications per year after 5 years. The additional cases ("slope: -1," "slope: 0," "slope: +1," and ":slope: +2") are similar, except that the number of papers published per year changes according to the specified slope.

The results of the simulation are summarized in the "Total" column of Table 1 and in Figures 1 to 4. Figure 1 shows the total number of publications at the end of the eleventh year for the various cases. As expected, the number of publications increases monotonically with increasing the publication rate. There are 30 publications for the case of rapidly decreasing production rate of "slope: -2," 110 publications in the case of constant production rate ("slope: 0") and 220 publications for the rapidly increasing production rate of "slope: +2."

The total numbers of citations (see Figure 2) show a similar trend. There are 10 citations for case No. 1, 260 for case No. 2, and 880 citations for the most rapidly increasing publication rate of case No. 6.

The trend of the CPP values (see Figure 3) is completely opposite to the trends of the total number of publications and citations. The CPP is the highest (CPP=10) for the "stop publishing" case. It decreases continuously with increasing the slope of the publication rate, reaching the lowest value (CPP=4) for the steepest increase of productivity considered in the case of "slope: +2." The calculated CPP values can be compared with the true citation frequency (one citation per paper per year) using CPP values normalized by the number of citation years (=10). These are shown in Figure 4. Obviously, there is no difference in the trends shown in Figures 3 and 4; only the scaling has changed. The value of the normalized CPP is one (as would be expected) only for the first "stop publishing" case. For the more productive research groups, the normalized CPP is significantly smaller than one, and it keeps decreasing with increasing productivity.

It is evident from this study that the CPP based on averages, as

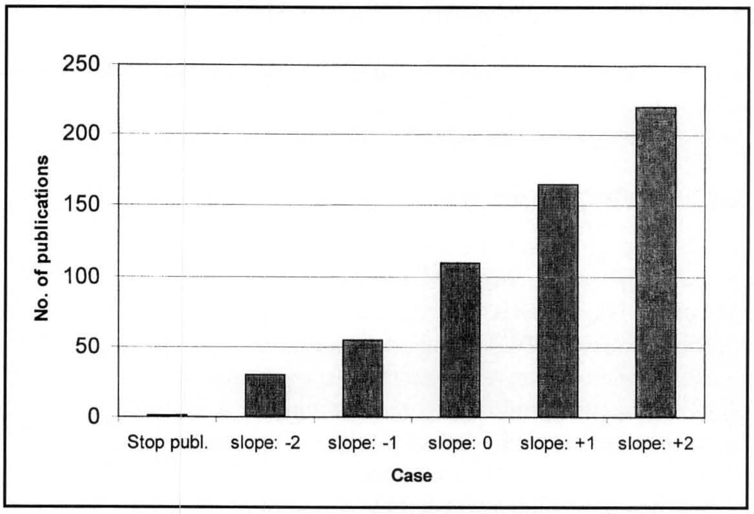

Figure 1. *Total number of publications in the various cases (time period eleven years).*

TABLE 1
Simulation Study of the Variation of CPP as a Function of Publication Rate with Constant Value of One Citation per Paper per Year

Case	*Description*	*Year* / *Year no. (1)*	*'89* / *0*	*'90* / *1*	*'91* / *2*	*'92* / *3*	*'93* / *4*	*'94* / *5*	*'95* / *6*	*'96* / *7*	*'97* / *8*	*'98* / *9*	*'99* / *10*	*Total*	*Weighted*
1	Stop publishing	Publication	1	0	0	0	0	0	0	0	0	0	0	1	10
		Citations		1	1	1	1	1	1	1	1	1	1	10	10
		CPP												10	1.00
2	Slope: -2	Publications	10	8	6	4	2	0	0	0	0	0	0	30	260
		Citations	0	10	18	24	28	30	30	30	30	30	30	260	260
		CPP												8.67	1.00
3	Slope: -1	Publications	10	9	8	7	6	5	4	3	2	1	0	55	385
		Citations	0	10	19	27	34	40	45	49	52	54	55	385	385
		CPP												7	1.00
4	Slope: 0	Publications	10	10	10	10	10	10	10	10	10	10	10	110	550
		Citations	0	10	20	30	40	50	60	70	80	90	100	550	550
		CPP												5	1.00
5	Slope: +1	Publications	10	11	12	13	14	15	16	17	18	19	20	165	715
		Citations	0	10	21	33	46	60	75	91	108	126	145	715	715
		CPP												4.33	1.00
6	Slope: +2	Publications	10	12	14	16	18	20	22	24	26	28	30	220	880
		Citations	0	10	22	36	52	70	90	112	136	162	190	880	880
		CPP												4	1.00

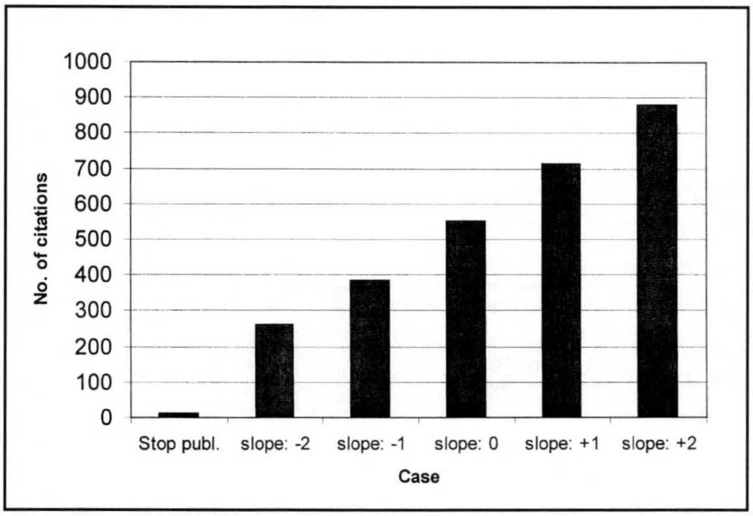

Figure 2. *Total number of citations in the various cases (time period eleven years).*

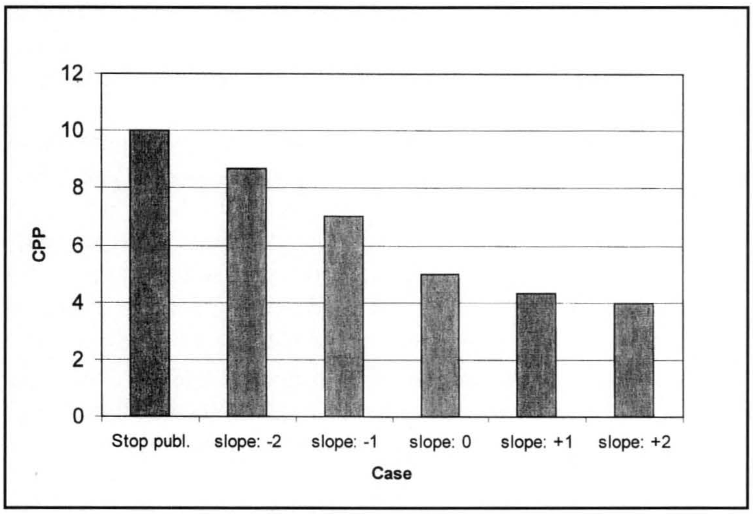

Figure 3. *The CPP values in the various cases (time period eleven years).*

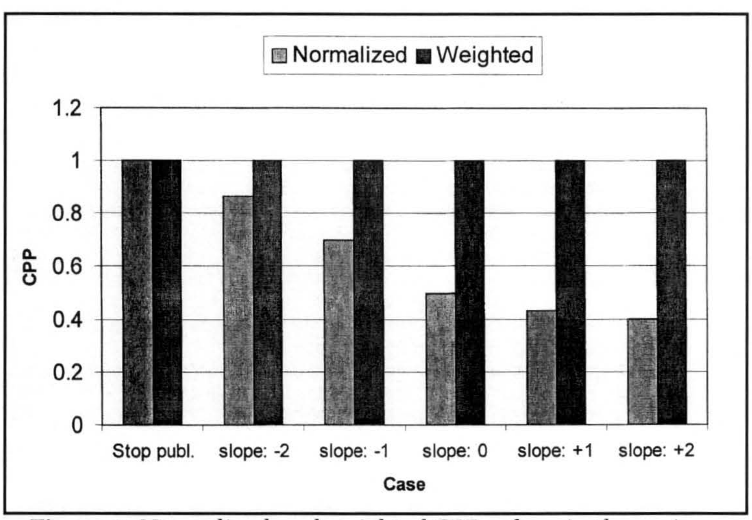

Figure 4. *Normalized and weighted CPP values in the various cases (time period eleven years).*

calculated in this study (and in *Science Watch,*[8] for example) does not represent the "impact" or research quality, since the impact is actually the same in all the cases studied here—one citation per paper per year. It definitely does not represent research productivity, since increase of productivity actually reduces the CPP. In the next section a modification of the CPP that eliminates the influence of the publication profile is proposed.

WEIGHTED CPP

When the CPP is calculated for a given time period (as in the example presented), the papers published at the beginning of the period have a higher chance to be cited than papers published in later years. This inequality can be eliminated by assigning to each publication a weight according to the feasible number of years for its citation. Accordingly, in an evaluation that considers a specified time period of n years, a particular paper that was published in the i^{th} year is assigned a weight of (n-i). To calculate the weighted CPP (WCPP), the total number of citations is divided by sum of the weighted publications (each publication is multiplied by its corresponding weight).

In the last column of Table 2 the calculation of the WCPP for the various cases is shown. In case No. 1 there is one publication in the first year, which should be included with the weight of (11-1)=10. Since there are ten citations of this publication the resulting WCPP is one. For the "slope: -2" case, there are ten papers in the first year with a weight of ten, eight papers in the second year with a weight of nine, and so on. The sum of the weighted publications is:

$$(10*10+8*9+6*8+4*6+2*5) = 260$$

Since this is equal to the total number of citations, the value of the WCPP is also one in this case.

In Figure 4 the value of WCPP is presented together with the normalized CPP values. It can be seen that WCPP obtains the expected value of one for all the cases, in contrast to the normalized CPP, which obtains different values for the various cases. Thus, in the WCPP the influence of the publication profile on the citation statistics is eliminated, and it correctly reflects an "impact" of a single citation per paper per year. Therefore, the WCCP is much more appropriate to represent "impact" of research than the CPP.

CONCLUSIONS

Using a simulation study, it has been shown that a CPP- based comparative evaluation of research groups of different publication profiles may yield absurd re-

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Publication Rate Profiles

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sults. The CPP is the highest for the less productive department and the lowest for a department with the most rapid increase of research productivity. It is also evident from this study that, in contrast to the popular belief and depending on the publication profiles involved, the CPP does not necessarily represent the "impact" and quality of research.

A new "weighted" CPP has been proposed, which eliminates the influence of the publication profile on the citation statistics and as such, is much more appropriate for measuring research impact. Obviously, in order to yield valid results, the WCPP must be referred to the world average WCPP of the particular research field.

The simulation study demonstrates once again that a comparative evaluation of research quality and productivity cannot be based on a single criterion. While the WCPP has herein proven to be more reliable in measuring "impact" than the CPP, it still may rank a stagnant (or even a declining-production research group) and a group of a rapidly increasing productivity the same. The WCPP can be heavily influenced, just as the CPP can, by additional factors such as the number of co-authors, the number of different research groups involved, and hidden self-citation. Therefore, it is always essential to look beyond various citation measures.

REFERENCES

1. Grossman, I.E., "Some Pitfalls with Citation Statistics," *Chem. Eng. Ed.,* **34**(1), 62 (2000)
2. Angus, J.C., R.V. Edwards, and B.D. Schultz, "Ranking Graduate Programs: Alternative Measures of Quality," *Chem. Eng. Ed.,* **33**(1), 72 (1999)
3. Braun, T., Letter to the Editor, *C&EN,* p. 6, Dec. 6 (1999)
4. Redijk, J., Letter to the Editor, *C&EN,* p. 6, Dec. 6 (1999)
5. Blazick, P., Letter to the Editor, *C&EN,* p. 6, Dec. 6 (1999)
6. Van Raan, A.F.J., "Advanced Bibliometric Methods as Quantitative Core of Peer Review Based Evaluation and Foresight Exercises," *Scientometrics,* **36**(3), 397 (1996)
7. Goldberger, M.L., B.A. Mahler, and P.E. Flattau (Eds), *Research Doctorate Programs in the United States: Continuity and Change,* National Academy Press, Washington, DC (1995)
8. "Chemistry that Counts: The Frontrunners in Four Fields," *Science Watch,* **3**(3), 1 (1992) ❒

In Memoriam

Sami Selim

Sami Selim was born in Cairo, Egypt on January 24, 1942, and passed away in Denver, Colorado, on June 27, 2000. He was educated as an undergraduate at the University of Alexandria (Egypt), and earned his MS in chemical engineering from Carnegie-Mellon and another MS in mathematics and a PhD in chemical engineering, both from Iowa State University. Prior to joining Colorado School of Mines (CSM) in 1982, he held faculty appointments at the University of Petroleum and Minerals in Dhahran, Saudi Arabia, and at Texas Tech. He was a member of the *Chemical Engineering Education* Publications Board for the last decade.

While his health problems limited his physical activity in later years, his mental activities remained extremely strong. We at CSM will remember "Dr. Sami" as the consummate professor: a brilliant lecturer, superb theoretician, gifted problem solver, and a world-class example of the phrase "absent-minded professor." He will be sorely missed by all of his friends and colleagues in the department, and by those students who were privileged to have benefited from his wit and wisdom, both inside and outside of the classroom.

A list of adjectives that might be used to describe Sami would almost certainly include scholar, educator, mentor, leader, colleague, and friend.

Scholar • A "learned person - one trained in a special branch of knowledge." Sami's knowledge of transport phenomena and applied mathematics was unparalleled in our department and university, and he was highly respected throughout the world in his areas of expertise.

Educator • Sami taught essentially every course in our undergraduate curriculum and every transport- and mathematics-oriented course in the graduate program. In his teaching career, he earned outstanding teacher awards four times.

Mentor • Perhaps Sami's greatest contribution was in his ability to mentor graduate students and faculty. He literally poured himself into a quest to instill a love of knowledge and discovery in our students.

Leader • Sami emerged as a true leader at CSM as a result of the work he did to introduce flowsheeting and computer-aided chemical process design throughout the undergraduate curriculum. During the mid to late 1980s, Sami spent a great deal of time working with Aspen Technology and Phillips Petroleum, learning how to perform computer-aided process simulation and then helping the faculty introduce this technology in every course in the ChE curriculum. Associated with this effort, he emerged as a leader in defining the content of what we teach in chemical engineering at CSM.

Colleague and Friend • All of us at CSM have memories of Sami that will last a lifetime. We all have treasured "Sami stories" that we won't forget anytime in the near future.

Sami is survived by his wife, Barbara. A scholarship fund in Sami's name has been established in the CSM Foundation. Please contact Bob Baldwin <rbaldwin@mines.edu> for instructions on donations.

Robert M. Baldwin
James F. Ely
E. Dendy Sloan