STRATEGIES TO ENHANCE WELL-BEING OF CIVIL ENGINEERING PROFESSION

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ABSTRACT: In a prior paper, the close interrelationship between seven key professional aspects in influencing the overall well-being level of the civil engineering profession was demonstrated. Here, operating on each of these aspects, a number of strategies are studied to assess their potential in enhancing the health of the profession. These address the need to (1) Improve public profile; (2) attract the best students to engineering; (3) graduate excellent students; (4) control the quality of professional engineers; (5) change market conditions for civil engineering services; (6) improve employment conditions; and (7) promote innovation, and research and development. The advantages of each strategy as well as the constraints acting against their implementation are identified. A consolidated solution of the most promising strategies is proposed. It is argued that short of this concerted effort, little incentive exists to affect major changes in the status of the profession. The immediate implementation of this comprehensive action plan is advocated.

INTRODUCTION

A previous paper by the writer (Bruneau 1993) described the pernicious cyclic linkage between various causes of professional dissatisfaction frequently raised by civil engineers in casual or more formal discussions and trade publications, namely (1) the poor public profile of the profession; (2) the difficulty in attracting the best high school students to engineering; (3) the declining technical excellence of graduating students; (4) the oversupply of engineers in a limited market; (5) the cutthroat competition affecting professional fees; (6) the relatively declining income of practicing engineers; and (7) the market pressure making difficult the fostering of innovative and high-tech practice through research and development. A straightforward closed-loop relationship exists between these factors, and the evolution or decline of the well-being of the profession is globally linked to the health of all these aspects of professional life. However, the previous paper concentrated solely on a presentation of the problems and possible ways to gauge their severity over future years.

Since the writing of that paper, displays of professional dissatisfaction in the trade literature has increased with an alarming frequency, to a point where the monthly self-grievances of the profession may give a casual reader the impression that the profession is terminally ill, whereas it may only be suffering a slight (hopefully temporary) functional disorder. For example, in three randomly selected separate but sequential recent issues of a well-known trade magazine, letters can be found from practicing engineers expressing opinions to the effect that universities are disconnected from reality (Diegel 1993; Porter 1993), that the profession needs further promoting to society (Pattison 1993) and surely does not need new members (Macone 1993; Powell 1993), and that more projects are needed to employ all these idle engineers (Couture 1993). In a single issue of another magazine, writers

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report that graduating students with excellent academic records cannot find employment in spite of good prior job experience (Cooke 1992), engineering salaries are low (Mattacchione and Mattacchione 1992), and forecasted shortages of engineers lack credibility (Oettershagen 1992). Although the profession is not yet close to the "waterline," these accounts cannot be simply dismissed as alarmist writings of idle engineers havng too much time to spare, particularly when the debate sinks to discussing whether it is too late to "save our profession" (Pennoni 1993).

After the publication of the earlier paper on this topic (Bruneau 1993), the writer received many positive comments, agreeing that his description of the problems plaguing the profession and his illustration of their interrelationship were very much "on target." Some confidential horror stories were also volunteered as evidence of the declining state of the profession. Unfortunately, beyond definition of the problem, the more difficult task remains the development of an effective solution to break the vicious cycle and retake control of the profession left for too long adrift under the forces of a free market. As often said, solving problems is the engineer's specialty, his raison d'être. Thus, redressing the state of the profession to its former stature should be a minor task, at best a formality. Wrong! A survey of the existing literature on this topic reveals that substantial complaints about the poor state of the profession have been voiced regularly since long before the birth of this writer, but since well-being of the profession has at best progressively deteriorated, all proposed solutions must have been either impracticable, ineffective, or incapable of consensual acceptance.

This paper proposes that (1) All efforts aimed at solving only one aspect of the problem cycle described earlier (Bruneau 1993) are doomed to fail since no incentive exists for an individual participant to initiate a process that would improve the overall state of the profession in the long run, but may be suicidal to that individual in the short run; and (2) any decision aimed at improving the state of the profession must also be economically viable if to be successfully implemented. Consequently, a realistic solution may be at best a compromise, far from an ideal but economically impossible solution. The writer cannot claim at this time to have knowledge of the actual solution to the problem. Some ideas are proposed, however, and reviewed in light of suggestions made earlier in the existing literature.

Since a comprehensive solution is advocated, the professional well-being chart is used to graphically illustrate the intended effect. This chart has been proposed (Bruneau 1993) as a method to monitor the seven key parameters identified as directly influencing the overall state of the profession. Essentially, each of these key parameters is assigned an axis on a multiaxis polar plot (Fig. 1); normalized performance indices were defined in Bruneau (1993) to measure the evolution or decline of the profession in each of these directions, but are not needed for the present discussion. On this chart, performance in each category can be gauged against a fixed benchmark in time: a curve "collapsing" closer to the center of the polar plot would be indicative of a progressively less appealing profession, whereas an expanding data set would reflect a dynamic and correspondingly more attractive profession. The objective is obviously to expand away from the center. Although it was implicitly acknowledged in the formulation of this method that all seven parameters are effectively linked and that progress or deterioration in one single category is bound to impact all the others in the long run, the persistent recording of a low "score" in one of those seven categories would undeniably point to where future efforts should be more intensively invested

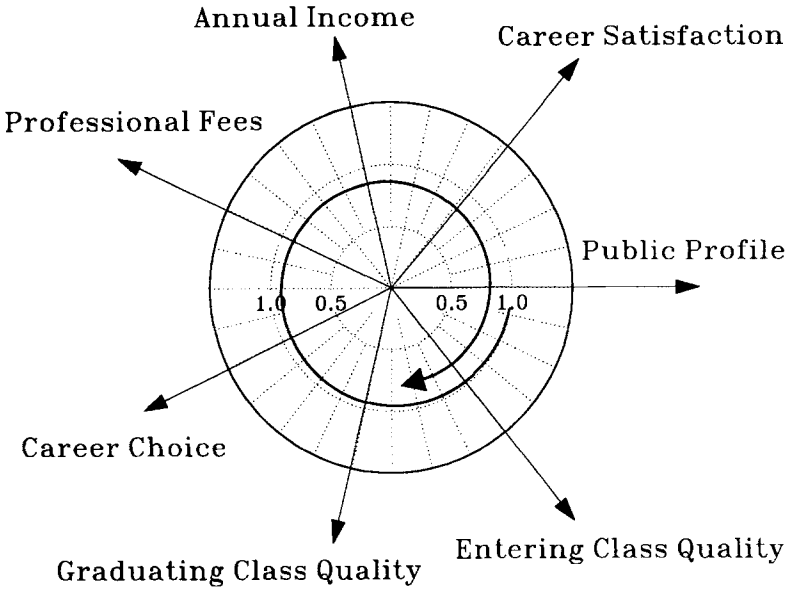

FIG. 1. Professional Well-Being Chart

to improve the state of the profession. The reader is encouraged to review Bruneau (1993) for a better perspective on the following discussion.

The acquisition of hard data is imperative, and without it, no concerted efforts can be orchestrated to improve the status of the civil engineering profession. However, for obvious reasons, the profession cannot afford to remain idle while awaiting the collection of this much-needed data, and preliminary strategies must be elaborated at once to, hopefully, thrust the performance indices of the professional well-being chart in an expanding direction. The present paper proposes a number of possible strategies to that effect, which are then consolidated into an advocated solution. The constraints against the implementation of each strategy are outlined.

At this time, the writer wishes to reaffirm that, in his view, there remains numerous positive aspects in the profession that make it a unique, challenging, and worthwhile career. This paper is written in the perspective that the reader also has the proper experience and objectivity for this appreciation, and can concentrate on the negative aspects without forgetting the numerous positive ones. A neophyte may lack this vision and should exercise care in reaching pessimistic conclusions with regard to reading this paper.

ENHANCING THE PROFESSION'S HEALTH

The objective of any corrective measure is to maintain or enhance the profession's well-being. In this section, ways to achieve this goal are examined for each of the key seven professional aspects.

Improving Public Profile

Advertisement and related propaganda are sometimes used to educate the public on the role of civil engineers in today's society (Reuss and Vogel 1989). Individual engineering firms usually excel at marketing their services to potential clients, but they cannot be expected to oversee and invest in

the education of the general public. Therefore, the responsibility to promote civil engineering achievements, whenever possible, rests with the various professional associations, some more committed to this goal than others. ASCE is to be commended for its efforts in that direction, and encouraged to continue. Unfortunately, a comprehensive concerted education effort by all professional associations remains elusive. The creation of a special fund by ASCE to capitalize on good opportunities to promote the profession was one positive step in this direction, and ASCE's mandate might even justify merging that program with the core activities funded from the mandatory membership fee, at a slightly increased membership cost, instead of relying on a separate voluntary contribution. However, in the current economical climate, many other professional civil engineering associations are under pressure to control or reduce their membership fees, and are unlikely to subscribe to a more intensive involvement on this matter. This is unfortunate, as the profession is nowhere near its saturation point of positive exposure. Numerous avenues have not been explored yet; for example, civil engineering achievement awards, which are good for the profession, could have worthwhile public educational value if the winning project and its engineers were profiled in a full-page ad in a major popular magazine (e.g., *Time*).

In Ontario, the image of the civil engineering profession has been undoubtedly enhanced, without much marketing effort, by the construction of the CN-Tower and the SkyDome, two awe-inspiring engineering achievements. In this perspective, it was puzzling for the writer during a recent visit there to find an exhibit on past Canadian *business* leaders at the top of the CN tower. Indeed, a golden marketing opportunity was lost to explain to the public how engineers can build a 553 m (1,815 ft) tower that resists enormous wind forces and to acknowledge the engineers who contributed to this success story (Who designed that tower anyhow?). Those who have journeyed to Europe will agree that due credit is more often given to engineers there. The exhibit in the Tower Bridge in London is one such example: it includes an easily accessible and instructive technical engineering story.

No publicity can more dramatically and positively influence the population than a few success stories, or, negatively, a few failures (Jacobs 1987). The media obviously need no assistance in composing headlines when major structural failures occur, particularly if deaths are recorded. One needs only to remember the extensive media coverage following the failure of the Hyatt Regency walkways in Kansas City or the dreadful images of the collapsed Cypress Freeway in Oakland following the Loma Prieta earthquake. Although society may sometimes accept failures as a necessary cost toward progress (Petroski 1982), more is to be gained by the profession when success stories are told.

Yet, all the professionally done presentations to educate the public and demonstrate that civil engineering is a good and respectable profession cannot distract from the bottom line in North America: The public largely measures the success of a profession by the money its practitioners make, and by their expressed job satisfaction. In particular, when parents formulate an opinion on this topic, it will ultimately be to encourage (by suggestion or less subtle steering strategies) their children to pursue a given career. For example, if one hears a dentist disenchanted by the routine of some of his or her work refer to that profession as "glorified plumbing," no matter how good the money, it fails to entice respect. The same goes for engineers.

Public respect cannot be bought; it must be earned. Therefore, promotion activities alone are easily defeated unless a more comprehensive solution is sought to redress other problems afflicting the profession.

Attracting the Best Students to Engineering

Obviously, the decision by a student to choose a particular profession is partly based on personal tastes, but the power of peer/parent/society pressures and misinformation should not be underestimated. Dissemination of information is an important activity in this regard. Universities spend a considerable amount of money to attract the best students. In the process, they attempt to be ethical and nondiscriminative between their various departments. University adiministrators generally assume that high-school students have already chosen their field of study and that the university's job is to cater to their needs. Hence, it is the respective faculties that usually endeavor to attract the best students.

Various strategies adopted for this purpose have been presented [e.g., Morris (1989); Reuss and Vogel (1989); Russell (1991); Shoemaker and Elton (1989)]. It is noteworthy that in those papers, the word "recruiting" is often used, quite unfortunately in the present writer's opinion, since these activities should not be compared to a military drafting operation. There is also a fine line to walk in all promotion activities to avoid sounding like used-car salespeople. If things are overdone, the entire process can lose credibility and backfire—the projected image must conform to reality. Moreover, since truly successful professions do not usually need to aggressively market themselves, an excessively glorified presentation of the civil engineering career (which is still, after all, a mostly anonymous profession) could raise suspicions from any critical audience.

The potential role of universities in conducting effective outreach activities to promote the strengths of its various departments to high-school students is well described by Shoemaker and Elton (1989), who emphasize the importance of providing valuable documentation to those who can be influential in the student's decision, and providing, whenever possible, hands-on exposure to the civil engineering field, such as during the holding of an annual open house. The presence of parents during open house activities is obviously preferable, often crucial, but that of high-school career counselors and teachers is probably even more important (one should never underestimate the power of nonparental guidance on a teenager). Unfortunately, few on high-school staffs ever visit campuses during those promotional days, and when they do, they are often shuffled into meetings where high-ranking university representatives are answering questions about program requirements and other administrative trivia. Yet these are the people who persistently misinform students about career decisions. In fact, this writer has observed that a significant number of civil engineering students had initially enrolled in architecture and later switched to civil engineering, simply because they were misguided by counselors unaware of the symbiosis between the architect and the structural engineer in construction.

To attract the best students, it is important to realize that many of them aspire to a prestigious profession. Unfortunately, even when an engineer becomes a leader in the profession, he or she remains an illustrious unknown (Jacobs 1987). The total absence of civil engineering role models worldwide is one of the issues most damaging to the profession: no Nobel Prizes, no media-worthy break-through discoveries, and no individual superstars (although some multinational engineering companies carry strong name rec-

ognition). This is a difficult mold to break; this issue is closely tied to the at-large marketing efforts and income issues addressed in the previous section. Universities can modestly assist in this direction by preeminently displaying a list of successful alumni with their professional titles.

A possible strategy to enhance the quality of the entering class in civil engineering, which seems to have received little support, is to limit enrollment. At first, this simple to implement solution is unlikely to happen, as it does not serve the universities and could even be suicidal for smaller universities. Public funding follows formulas that take the size of entering classes into account, and limiting enrollment cannot be beneficiary in a short-term perspective. However, evidence suggests that entering civil engineering students are the poorest of all engineering students (Muspratt 1986; Morris 1989), and, to make matters worse, students failing other engineering disciplines often are "recycled" in civil engineering (Laursen 1989). Some universities also have an open-door approach that encourages nearly any high-school graduate to try his luck in engineering—a rather unwise policy of nonexcellence potentially most damaging to the public perception of engineering. All these factors promote a condition of low self-esteem among many students for whom civil engineering has been a career lifeboat. Incidentally, these could be the very same people who, following graduation, will have no shame in cutting to the bone their engineering fees in accordance to the low self-assessment of the worth of their services. In that perspective, limiting enrollment can be positive over the long-term, but of course only if conducted simultaneously with the other measures proposed herein.

Limiting enrollment can be achieved by restructuring the engineering curriculum to convert engineering into a professional degree for which successful completion of a stringent pre-engineering program is necessary (Schrader 1972; Pletta 1974; Pletta 1980; Kersten 1982; Ward 1983; Vild 1984; Pletta 1987) or by imposing nationwide admission exams, as done in some other countries, with a minimum passing mark necessary to gain admission to the engineering program. Either way, the entering class must truly feel it has earned the privilege to join an engineering school, one important step toward higher professional self-esteem, and overall betterment of the profession. However, without a coordinated effort, as proposed herein, funding constraints and intrauniversity multidisciplinary politics makes this goal beyond reach. In fact, in the current climate of fiscal restraints, pressures to reduce the bachelor's degree in civil engineering to a three-year program in publicly funded universities would be more likely, and maybe consistent with the historically declining status of the profession.

Graduating Excellent Students

As discussed elsewhere (Bruneau 1993), it is grotesque to suggest that a 60% passing grade is a convincing indicator of proficiency on a given topic. This is particularly so taking into account the fact that some professors will round up a 55% to a 60% to avoid long debates about grades and that other normalizing forces are at work (with the contribution of assignments and lab reports to the total final grade, where teamwork is customary and parasitic students are often being towed by others, one could maybe pass with a roughly 40% performance in exams). While mediocre students can play the system and manage to graduate, albeit not totally stress-free, it is obviously of no advantage to the profession (Bruneau 1993) to graduate specialists of mediocrity.

A first set of corrective measures is needed to ensure that graduating students have developed a manifest strength in at least one of the aspects of civil engineering, so that no student graduates with a 60% average in nearly all of his/her courses. This goal could easily be reached by requiring that a 80% average be obtained in at least one student-selected field of specialization (i.e., structural, water resources, geotechnical, environmental, etc.) in order to graduate with a civil engineering degree. For each subdiscipline for which the student would have met this minimum criteria, a distinct certification would be integrated into the diploma. However, this would be a purely academic (and manipulable) exercise unless enforced by the professional registration mechanism. Thus, to be allowed registration and practice in any of the subfields of civil engineering, a person should have obtained the proper academic certification. This would be true, regardless of engineering becoming a professional degree.

These are stringent new propositions, but they should cause no problem to the majority of students. At worst, they would narrow the career opportunities of poorly performing students. They also transmit a clear message that engineering is work, not a birthright, and indirectly raise the standards in North American engineering schools. To pacify those who allege that the technical knowledge learned at the university is not used after graduation, a management option could be added to the list of subdisciplines. Clearly, this is an open proposal to short-circuit market forces; it is consistent with the beliefs of many that, based on general economic principles, the market rules are detrimental to the profession (Bruneau 1993; Jacobs 1987; Alpern 1976; Israni 1981; Alexander 1991).

The present writer also recommends the creation of a mandatory final-year practical course on the marketing of engineering services, less abstract that the general economics Mickey Mouse courses currently part of most curriculums and totally irrelevant to civil engineers. A good awareness of the market forces acting on the profession to reduce the well-being of its members should be gained in this course, and methods to operate within these pressures should be taught at once, using case studies whenever possible.

Obviously, it is implicitly acknowledged that the need for a high-quality faculty, well-equipped and extensive laboratory facilities, and well-trained support staff, is equally important in ensuring the quality of graduating students. This has already received considerable attention elsewhere (Hansen 1972; Ward 1983; Hawkins 1986; Malina 1986) and is not reviewed here.

Finally, an earlier suggestion that "ingenioring" be substituted for "engineering" (Pletta 1987) in all future degrees (and professional titles) is also worthy of further consideration to disassociate the profession from the sempiternal and misleading image of locomotive drivers.

Controlling the Quality of Professional Engineers

There is currently no uniformity in the examination requirements for professional registration across North America (Kersten 1982; Tynes 1973). In Ontario, graduation from an accredited civil engineering program given in a Canadian University combined with the successful completion of simple law and ethics exams is sufficient to acquire the general title *P.Eng.* without attached specific specialty designations (such as civil or mechanical). In some states, technical examination is required for the obtainment of the "civil engineering" title, and specific additional exams must also be successfully passed for the right to use the protected title of "structural engineering".

The philosophy behind the registration act is presumed to be the same everywhere, to ensure that adequate standards are maintained across the profession, for the protection of the public. Yet, the way this obligation is fulfilled varies dramatically. The Canadian system puts its faith in the excellence of the university programs controlled by a national accreditation committee; this seems justified in light of the Gourman ranking of North American universities (Gourman 1988, 1993). The American system favors an independent control.

The present writer favors a restrictive approach where a specific civil engineering designation must be obtained by the successful completion of a rigorous examination of the candidate's technical capabilities, that is, separate examinations would be required for each of the special titles of structural engineer, environmental engineer, and so on. The prior obtainment of the aforementioned academic certification in the pertinent subdiscipline (with the aforementioned contingency) would be necessary for eligibility to the professional exam. Special provisions for the registration of landed immigrants would be needed to ensure equivalently high standards of practice. A nationwide registration exam might even be comtemplated, particularly in the era of global markets, but is unrealistic at this time given the phenomenal political hurdles toward this goal.

A tightening of quality control through the registration procedure affects many other of the key aspects identified on the professional well-being chart. In particular, students aware of the existence of this engineer's "bar exam" would gain a new perspective on the value of their studies and on the engineer title. This would also enhance the legitimacy of the title. Inevitably, the public would learn that it is earned through competency as demonstrated by the passing of stringent exams. The level of difficulty of these exams as well as the maximum number of failures permissible before being denied further attempts would be left to the judgment of the professional associations, as a first measure, but eventually determined by a national consensus.

The objective is not to gain notoriety and artifically control the size of the profession through abnormally high failure rates, a motive sometimes attributed to the bar exams of some provinces/states, but rather to perform an uncompromising quality control of the profession early in the game. Although some may object to this proposition by fear of creating a shortage of engineers, the present writer has already professed (Bruneau 1993) that even the current shortage of "good" engineers cannot be solved by the graduation of a large number of mediocre engineers. If anything, the elimination of poor-quality graduates from the system, by denying them access to the profession, can only put upward pressures on salaries by controlling the supply (a problem easier to manage, for a change).

Incidentally, shortages of civil engineers for the near or far future were repeatedly predicted over many decades [see Alpern (1976) for an historical overview] but have yet to materialize. This systematic delusion has raised serious doubts as to the objectivity of these studies (Israni 1981; Alexander 1991; Oettershagen 1992), frustration and anger from members of the profession (Cooke 1992; Macone 1993; Powell 1993), and even suggestions of a conspiracy (Alpern 1973, 1986). Further calls for future shortages have lost all credibility. For the record, the U.S. Bureau of Labor Statistics (*Education* 1989) currently forecasts that demand for scientists and engineers in the civilian sector will increase by 36% between 1986 and 2000 in the United States and the Canadian Engineering Human Resources Board predicts a 25% increase in demand for (and shortage of) engineers between

1991 and 2000 in Canada (*Supply* 1992). Not insignificantly, an appendix of the latter report states, "When interpreting the forecast presented in this report, it is important to remember that there are no feedback links between the supply and demand models. This means that while in the 'real world,' the labour market for engineers will usually be approximately balanced—i.e., supply being roughly equal to demand, the model results can show significant imbalances. This is because in the model, no adjustments occur in response to imbalances between supply and demand . . . . the results of the model must be interpreted with care." The hidden message in this most elegant statement is clear.

Changing Market Conditions for Civil Engineering Services

At best, engineers currently price their services at less than half of what lawyers typically charge; it is often said to be the maximum the market will bear. Given the ratio of the cost of engineering services to the total project cost (sometimes less than 0.5%), "what the market will bear" often actually means "how low is the competition willing to go to get the contract." Understated here, is that engineers "have failed to convince others of the importance, and thus the value, of the service they perform for society," largely because they are not themselves convinced of their worthiness (McMinn 1973).

Society has come to think of engineering services as an interchangeable commodity instead of the unique work of highly qualified professionals. Consequently, engineers have been thrown into the brutal arena of price competition (Giberson 1980). Still, oddly enough, the existing pressures for competitive pricing of civil engineering services are partly attributable to the engineers. Although on the surface, one cannot blame owners for attempting to get the lowest price on any product, few of these same owners would select their dentist solely on the speed of his drilling without inquiring about the associated pain level. Thus, the failure to stress to the client the relationship of quality and other associated benefits to higher professional fees lies largely within the engineering community itself. The importance of educating owners regarding the price/quality relationship has been emphasized elsewhere (Bruneau 1993). It should be clear that lower engineering fees do not necessariliy translate into lower construction fees (Mirza 1993). Furthermore, quality of service, accountability to public health and safety, as well as integrity and liability all risk erosion when engineering is driven by purely competitive market pressures (Merrifield 1973; Tulloch 1980). Fortunately, but slowly, more clients come to understand this principle (Esterbrooks 1989).

Qualification-based procurement of engineering services has been promoted as one logical client-engineer model (DeFraites 1989). The need for prequalification, even if not the sole decision factor, is also emphasized by others (Giberson 1980; Tulloch 1980). In most of those procurement systems, the actual "cost" of client education is still borne by the consultant, a "subsidized" activity that may not be applicable or economical for all projects.

Basic macroeconomic principles recognize that undue profits can be generated by price-fixing and/or monopolistic situations, and antitrust laws have been enacted in most capitalistic societies to foster fair competitive market conditions. Unfortunately, as stated earlier, recent history has demoted civil engineers' services to the level of commodities that must comply to these laws (Goodkind 1976; Giberson 1980), even though price collusion in the

civil engineering profession would be nearly impossible to establish, and consequently to prove if challenged legally (Goodkind 1976). Thus engineers are now playing the market game, some against their will, others for idealistic purposes. This is somewhat unfortunate, in view of the substantial benefits available to those who possess monopolistic advantages. Indeed, if not for fear of legal repercussions, it would be purely insane not to strive toward that monopolistic direction. Quite shrewdly, other professions have indirectly managed to develop a stranglehold on their market by charging standard fees for various services; for example, taking advantage of the blur between fees and salaries inherent to their profession, most (if not all) dentists and medical doctors, to name only a few, charge their services at the rate recommended by the professional associations, which are coincidentally equal to the amounts insurance companies (or governments) are willing to pay for these services. In other professions, unions have had a major impact in attenuating fluctuations in market conditions. It is important, as engineers, not be left alone playing an obsolete game. Thus, as a minimum, and at the risk of brushing with the law, professional associations have a moral duty to establish and promote a recommended minimum rate structure for guidance as to what constitutes adequate fees to provide quality engineering services while being able to ensure protection of the general public. As a direct implication, clients contracting with engineers at less than the recommended rate would acknowledge a shared responsibility in the risk (although not the certainty) that engineering services purchased may be of a lesser quality and/or oblivious to certain aspects of public safety.

As a complementary measure, to account for the difficulty and variability in pricing a creative process in number of work-hours, the present writer would promote awarding any engineering contract to the submission closest to the avarage of all engineering fees submitted (maybe after throwing out the highest and lowest ones). If there is indeed a cost to every product of reasonable quality, the submitted proposals should spread somewhat around this mean value (and mean quality), and the firm with the best perception of what this true cost is deserves the contract. This is not unlike a similar proposal suggested for competitive bidding in the construction industry (Nicholson 1991). Most clients, like us when shopping, are pleased with a reliable standard quality item, except when the standards are low (which is hopefully not the case in North America) or when specifically seeking a higher-quality or luxury item, and would be served by such system. The professional associations should pressure various public agencies to steer their contract awarding precedures in this win-win direction. Although there are still many marketing and positioning strategies available to civil engineering firms to gain an edge in the current competitive environment, this suggestion deserves consideration on its own merit.

Improving Employment Conditions

Hall (1991) recently published on the front page of the business section of a well-circulated newspaper the median pay for selected nonhourly occupations in the United States. On that pay scale, among other things, the yearly earnings of a junior engineer was shown to be comparable to that of an employment interviewer, a personnel assistant, or a general accountant, and definitively less than a customer-service supervisor, a sales representative, or a maintenance supervisor. Not to forget, the engineer's pay is losing ground every year (*Engineers'* 1993). The damaging effects of such an article on the public perception of the civil engineering profession is

TABLE 1. Top Salaries for Various Occupations in Ontario in 1993 (Leung 1993; Hill 1992) versus Number of Years Needed by Ontario Engineers (All Disciplines) to Reach Comparable Salary (*Ontario* 1992)

Occupation (1)	Top salary (Canadian dollars) (2)	Number of Years since Graduation Needed by Engineer in Ontario to Reach This Salary	
		Mean (3)	Top decile (4)
General/lieutenant general	128,900	>35	>35
Major general	109,500	>35	>35
Chief librarian Ottawa Public Library	103,828	>35	>35
National research council principal research officer	81,934	>35	16
Federal government lawyer	78,500	>35	14
Ontario government psychologist	77,236	>35	13
Ottawa fire platoon chief	70,050	34	10
Canada Post computer programmer	68,234	27	10
Ontario Provincial Police staff sergeant	64,599	21	7
Federal foreign service officer	63,325	21	7
Federal helicopter pilot	63,203	21	6
Ottawa secondary-school teacher	59,400	15	
Ottawa city senior administrative officer	56,374	13	5
Air-traffic controller	54,828	11	5
Canadian press reporter	52,676	9	4
Ontario prison trade instructor	51,742	9	4
Ontario Provincial Police first-class constable	50,468	9	4
Ottawa first-class firefighter	50,168	9	4
Ottawa Board of Education programmer analyst	49,171	9	3
Bell Canada technicial	47,580	7	3
Children Aid Society senior caseworker	47,267	7	3
Ottawa Hydro lineman	46,009	7	3
Brewers retail cashier-checker	43,243	5	2
Ottawa-Carleton bus driver	36,816	2	0
United Parcel Service full-time driver	33,800	0	0
Bell Canada operator	31,668	0	0

incommensurable. Although the engineer's income is known to appreciate rapidly during the first years of employment where valuable practical experience is gained, it is also known that it will remain lower than that of other comparable professions. This is further substantiated by Table 1 and by knowledge that the ratio of the income of an engineer with 25 years experience over that of a recently graduated engineer has fallen from 3.8 in 1939 to 1.8 in 1970 (Hajj 1973). Moreover, civil engineers have, for a long time now, seen the pay of unskilled construction workers exceed theirs by far (Smyers 1972), and one may question whether engineers of the near future will become like coaches in professional sports, that is, mostly without real authority and disposable. This is largely a consequence of the aforementioned competitive pressures within the profession (Bruneau 1993).

To curtail market pressures on salaries, there are at least two proven

techniques in economics theory: the establishment of (1) A union; or (2) a captive market. In North America, trade unions have been most effective in leveraging their members' power to negotiate pay scales by far exceeding those which would otherwise be dictated by supply/demand economics. However, unlike unskilled workers, practitioners of liberal professions are generally uncomfortable with the idea of unionization, and so are engineers. Although pressures toward unionization were strong in the 1950s, most engineering unions of that time eventually fell apart after a few years (Hajj 1973). Other such pressures in the 1970s were felt in answer to salary, professional and individual dissatisfactions (Hajj 1973; Smyers 1972; McMinn 1973) but engineering unionization in North America has remained marginal to this day. It appears that this lack of interest is mostly because (1) The ambition and strong individuality of most engineers is incompatible with the generally constraining framework associated with unions; and (2) unions are typically perceived as protecting otherwise exploited workers, and some fear that a large-scale unionization of civil engineers would project, by association, a rather negative image. Thus, although engineers' unions are already in existence in some large public agencies in North America, they are unlikely to be the solution to the salary woes of most engineers in North America.

As far as captive markets are concerned, engineers have not benefited from a societal or organizational structure allowing them to narrow their market to become sole suppliers, as a group, to practically a single client. The fact that most tasks performed by dentists and medical doctors are amenable to a series of standard procedures of well-identified scope to which a fixed cost can be assigned, has given these professionals, with the complicity of dental/health insurance companies, a nearly captive market. Unfortunately, the conditions necessary for the establishment of such a monopolistic market are contradictory to the nature of civil engineering services.

Engineers are also much too busy competing against each other to be willing to give up control on salaries. In fact, when trying to penetrate new markets, some are even willing to work at a loss! Consequently, direct control of salaries appears highly improbable. It is noteworthy that in at least one Canadian province, there is a law dictating what shall be the minimum hourly wage paid to an engineer, but unfortunately it was enacted more than half a century ago and is now essentially ineffective, since that hourly wage has never been updated to account for inflation. Nonetheless, this law originated with public protection in mind, the rationale being that engineers hired below a given minimum are likely not trustworthy. In this light, the concept of a minimum hourly rate for professionals is not that unreasonable and may deserve some reconsideration.

It is also futile for civil engineers to wait for society alone to recognize that compensation should be commensurate to level of responsibility, since history has failed to answer engineers in this regard (Maddock 1978; French 1979; Israni 1981). Quite on the contrary, it is generally accepted that compensation for civil engineers is fundamentally controlled by supply-demand forces alone (Smyers 1972; Maddock 1978), failing other control mechanisms. In this perspective, the appreciation of earnings can only be a consequence of improvements of some of the other key professional well-being aspects previously identified. Thus, to gain control on the quality of employment conditions, a strong and effective national organization representing all civil engineers and capable of dealing with issues of supply and

demand by vertical integration of education, training, licensing, and policing of their members is absolutely needed. Unfortunately, although such an organization exists for other professions (Furman 1972; Thorn 1972; Israni 1981; Kersten 1982), it is lacking for engineers in North America (Maddock 1978). The birth of this powerful organization is hard to foresee, on one hand because many engineers are conditioned and resigned to their fate, faithful to a system which has inbred low self-esteem, and on the other hand because most are employees, a condition generally not conductive to the spontaneous generation of an efficient and organized professional leadership with the above goal in mind. As an illustration of the former, many engineers would argue it insane to believe that professional engineers should be paid twice (or more) what they are currently earning, while there is a priori no compelling reason why not.

Fiscal Policies Highly Favorable to Research and Development

Both voluntary and coercive measures are possible to induce civil engineering firms into more innovative practices. Clearly, if civil engineering contracts were awarded to those closest to the average of all fees submitted, this would automatically produce a strong incentive to produce a higher-quality product integrating innovative ideas. In the absence of this environment, other strategies are possible.

Tax-deductions of 150% for each dollar spent in research and development could be a strong enticement for many firms to consider innovation. Such a measure could be difficultly enforceable, and, given the lax definition of corporate research in civil engineering, the work conducted by such organizations is likely to emphasize development more than research. Nonetheless, as North America needs to remain a more technologically advanced society to survive in the global market, tax breaks related to research and development will bring much larger long-term benefits to the economy than deductible entertainment expenses.

On the coercive side, mandatory continuing education as a condition for continued registration can be contemplated (Ingersoll 1975). As many engineers move into management positions at the midpoint of their career, the engineering body at large would definitely resent such a measure. Yet the sole purpose of professional registration being to ensure that high quality standards are maintained for the protection of the public, the imposition of continuing education is most consistent with that mandate. In the sixties, half of an engineer's professional and technical knowledge was becoming obsolete within 30 years. Today, this "half lifetime" of knowledge is estimated at about 9 years ("Seismic" 1991). Hence, this is an idea whose time has come. Many engineers already take continuing education in their own hands by keeping abreast of recent advances in the field. Whether to make or not to make it a mandatory and controlled exercise has been strongly debated in the past, and some professional associations have already taken a stance on this issue, usually a lax one. In the present writer's philosophy, a more controlled approach is by far superior.

Another coercive, albeit less drastic, measure could simply be to require public agencies to demand, in all their requests for proposals (RFPs), that civil engineers demonstrate which innovative ideas they can bring to the project to enhance its quality or save money during construction; ranking between proposals would obviously need to give this item its proper weight. Engineers employed by public agencies would be instrumental in bringing forth such changes.

RECOMMENDATIONS

In the previous section, a number of possible strategies to enhance the quality of the well-being of the civil engineering profession were presented. Undoubtedly, many can have a direct positive impact on the quality and cost of civil works, and, therefore, on the well-being of the society at large. The objective of all these strategies is to operate on the professional well-being chart by forcing its expansion in the positive direction, shown in Fig. 2. The writer contends that the current well-being of the civil engineering profession is the subject of a sufficiently high number of concerns (Bruneau 1993) to justify the implementation of some of these interventions at once. Evidently, few (if any) of these interventions are possible or even realistic short-term solutions if attempted outside the framework of a concerted effort. Hence, to ensure that high standards are the norm for all practicing engineers and that their services are duly compensated, the following eight actions are proposed.

1. A national association of civil engineers must be established with the mandate to comprehensively reform the educational, training, and licensing requirements of the civil engineering profession. The first goal of this association is to perform an uncompromised redesign of the profession at all levels in order to enhance its status and the quality of both its practitioners and their services. Its second goal is to develop the necessary political framework to allow this transition within a set timetable. Obviously, for this restructuring of the profession to be implemented, the new association must have the enforcement power of both an accreditation board and a licensing board, must be able to police its membership to ensure quality for the protection of the population, and must simultaneously act as a learned society.
2. The above national association must be responsible for the at-large promotion of the profession to the general public, through traditional publicity and by the judicious development of information displays on works of engineering significance.
3. The engineering curriculum must be restructured into a professional degree, with approximately two years of preengineering education, followed by a professional engineering degree of six years, divided into four years of formal course work and an internship of two years in engineering practice, preferably involved in design-oriented activities. With the internship integrated to the degree, it is only natural that enrollment to this professional engineering degree must be limited. Furthermore, a complete overhaul of the curriculum must ensue.
4. The civil engineering diploma must include a certification in one or many subdisciplines(s) in which the student has obtained a grade of 80% or more in a series of designated courses pertaining to each subdiscipline.
5. The title *Professional Engineer* must be supplemented by descriptive titles, such as *Structural Engineer* or *Geotechnical Engineer*. The right to practice in a given specified subdiscipline is restricted to holders of the proper title, although there is no limit to the number of such titles an engineer may hold. For the obtainment of this title, two years of general postgraduation additional training, the pertinent subdiscipline certification on a civil engineering diploma, and the successful completion of technical exams administered by the professional association, all are necessary. Re-

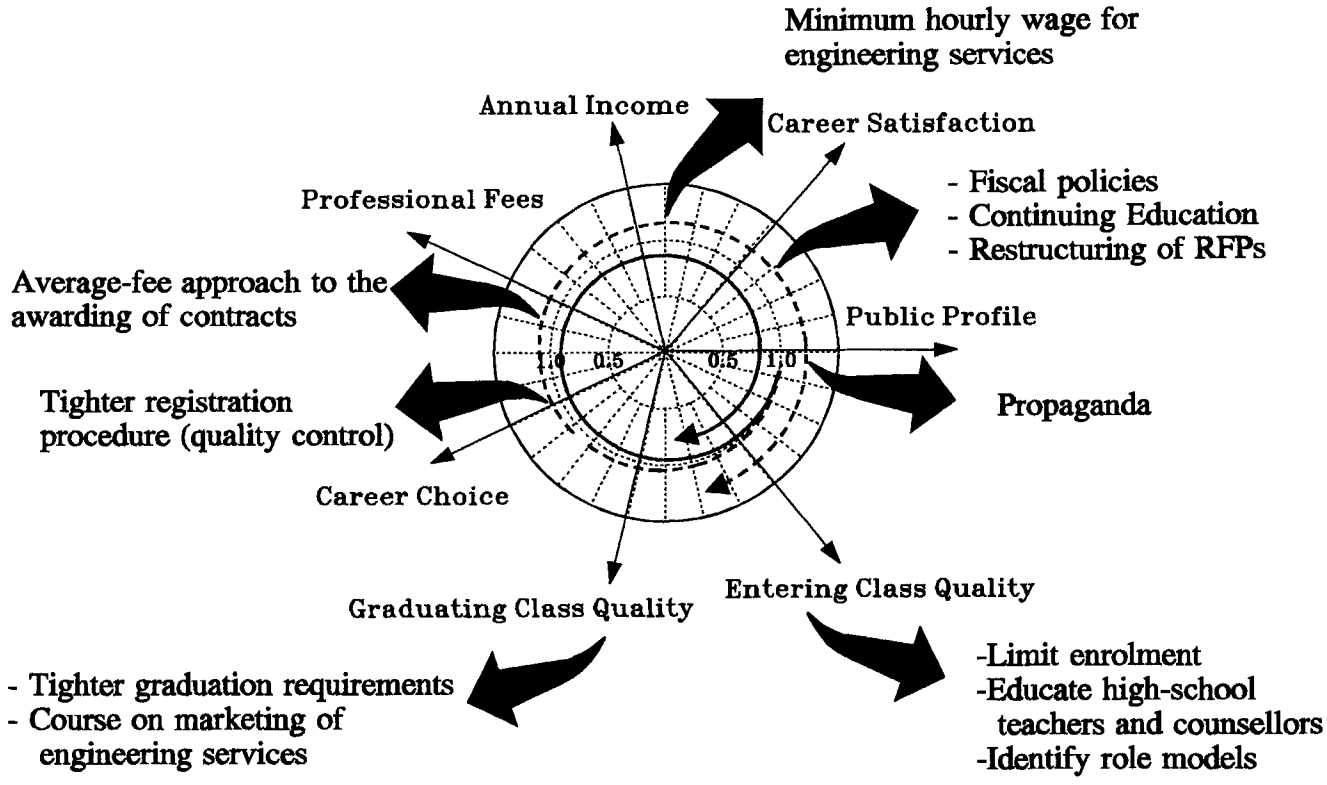

FIG. 2. Direct Interventions to Enhance Well-Being of Various Key Professional Aspects of Civil Engineering

quirements of continuing education must also be established as a condition of extended registration.

6. A recommended engineering fees structure must be established and promoted as guidance to what constitutes adequate fees for the provision of quality engineering services, all while ensuring protection of the general public. It should unambiguously be understood that work performed for a lesser fee at the request of the client carries an omen of shared responsibility in the event of unsatisfactory performance.

7. Public agencies must be encouraged to award engineering contracts to the submittal closest to the average of all submissions, instead of the lowest-priced one. The advantage in terms of quality, construction-cost reductions, and overall higher technology and innovations in North American society are to be stressed.

8. The association of civil engineers is to lobby the government for the establishment of a 150% tax deduction for every dollar invested in research and development in civil engineering.

While all these measures will enhance the quality of training, the quality of practice, the quality of the engineered product, and promote a dynamic approach toward innovations and research and development in civil engineering for the benefit of the society at large, it should be reemphasized that none are likely to occur without implementation of the national association of civil engineers proposed in item 1. For example, as revealed by the existing literature, there has been no lack of willingness to restructure the engineering curriculum; only lack of a propitious climate conductive to these changes. Similarly, a more complex registration procedure including extended examination will entail higher professional registration fees, which can difficultly be justified unless paralleled by increased earnings of these same professionals.

CONCLUSIONS

A number of interventions aimed at enhancing the overall well-being of the civil engineering profession are studied, hopefully to redress a pernicious malaise perceived by an increasing number of members within the profession. For each of the key professional aspects affecting the well-being of the profession, as identified in Bruneau (1993), strategies believed to have the most significant positive consequences on the future of the civil engineering profession are proposed. Finally, a comprehensive strategy integrating the most promising elements is proposed. It is argued that short of a concerted effort, little incentive exists to affect major changes to the status of the profession.

The writer suggests that the profession cannot wait any longer to act. The proposed plan, although purposely schematic, is one positive step toward enhancing the well-being of the profession. It should hopefully stimulate a constructive debate on that topic. At this time, this debate should not be distracted by details or steered by the few engineers who fear they may not survive an extensive restructuring of the profession.

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