A Sustainable Cohort of Professional Civil Engineering Graduates? Uncovering the United Kingdom Graduate Crisis

David J. Edwards
Department of Civil and Building Engineering, Loughborough University, United Kingdom
d.j.edwards@lboro.ac.uk

Andrew R.J. Dainty
Department of Civil and Building Engineering, Loughborough University, United Kingdom

Peter E.D. Love
Management Information Systems, Edith Cowan University, Australia

Undergraduate applications to civil engineering courses have been declining at an alarming rate despite the industry's healthy economic activity. Concerns abound as to the long-term impact of this decline as the sector is already suffering skills shortages across virtually all of its occupations. This paper investigates the likely future trends in undergraduate admissions to civil engineering degree courses based on an analysis of Universities and Colleges Admissions Service (UCAS) statistics for the period 1994 to 2000. The analysis reveals that applications have sharply declined over this period from 5,104 in 1994 to 2,905 in 2000. This trend is then modelled using a bivariate quadratic and cubic model equations to determine the volume of future applications. With an R^2 of 0.99 and a mean absolute percentage error of less than one per cent, the model appears to be robust and reliable. By contrasting graduate intake with sector turnover, the paper explores whether any significant correlation exists between market buoyancy and the attractiveness of a professional civil engineering career. Model forecasts over a six-year period suggest that applications will continue to decline, albeit at a slower rate. The likely causes and implications of the trends are discussed and measures proposed to stem the decline in popularity of civil engineering degree courses.

Graduate shortages, forecasts, manpower planning, civil engineering, United Kingdom

INTRODUCTION

There has been a rapid expansion in the numbers of students entering Higher Education (HE) over the last decade in the United Kingdom. Between 1994 and 2000 the number of applicants accepted into HE courses rose by over 20 per cent (UCAS, 2002). These quoted figures are broadly in line with the Government's widely publicised target of a 50 per cent increase in HE participation for 18 to 30 year olds by 2010 (DfES, 2003). However, while the trend in HE participation and growth continues, the future looks less optimistic for civil engineering. Despite the growth in admissions to degree courses generally, the number of applications and entrants to civil engineering courses have declined at an alarming rate over the same period. Indeed, it has recently been forecast that construction degree courses could face extinction within ten years if the present rate of decline continues (Clark and Nikkah, 2003).

Against this backdrop, this paper explores whether concerns over falling applications to undergraduate civil engineering courses are justified or merely based upon conjecture. A secondary analysis of UCAS admissions data is presented, from which a predictive model is developed which forecasts the likely numbers of future enrolments. Based upon model predictions, conclusions are drawn as to the likely severity of the undergraduate skills crisis in the medium term. In addition, suggestions are proffered as to how the profession can begin to address its apparent current unpopularity as an undergraduate discipline.

THE DECLINE OF CIVIL ENGINEERING UNDERGRADUATE ADMISSIONS

Byfield (2001) explored entrant figures for undergraduate admissions to civil engineering courses for the period 1996 to 2001. Byfield's analysis illustrated the fluctuating popularity of civil engineering courses since 1966, followed by an unrelenting downward decline in terms of the numbers of home applicants accepted on to both degree and HND courses since 1993. Since 1997, a decline in the numbers of overseas and EU applicants accepted to United Kingdom courses has also been apparent. Byfield's alarming findings are supported by anecdotal accounts and speculative industry reports. For example, according to the New Civil Engineer (2002a), 72 per cent of United Kingdom universities' civil engineering courses are effectively unviable, 27 per cent of civil engineering graduates do not join the industry upon graduation, and in the last five years, applications have fallen by 32 per cent and acceptances by 29 per cent. Indeed, almost 70 per cent of United Kingdom civil engineering departments say they have severe to critical problems recruiting students to their courses (Mylius, 2002). More pessimistic projections have even suggested that if the current decline is maintained, there will be *no* applications for United Kingdom civil engineering degree courses by 2007 (see Soudain, 2001).

The shortage of construction graduates is by no means restricted to the civil engineering sector. Cavill (1999) for example reported on the paucity of quantity surveying graduates entering the industry in 1999 in comparison to the early 1990s. She found that for some courses, the number of applications had declined by almost 75 per cent. Dainty and Edwards (2003) reported on the decline in applications to building construction courses within the United Kingdom. Their forecast predicted that the building sector is ill-equipped to cope with expected future demand. Indeed, in his recent review of research and innovation in the industry, Fairclough (2002) commented on the delimiting effect that falling undergraduate admissions could have on the future development of the construction industry. He commented that

> …there has been a dramatic decline in the numbers of new entrants on construction-related degree courses. If the current rates of decline were to continue into the future, the number of students in the built environment would rapidly collapse. By 2009 the number of applicants to civil engineering courses would have fallen to 0, while the last applicant to building and construction courses would enter university by 2012. So far, the declining trend line shows little signs of bottoming out. (Fairclough, 2002)

THE IMPLICATIONS OF THE DECLINE IN POPULARITY OF CIVIL ENGINEERING DEGREE COURSES

Construction Industry Training Board (CITB) forecasts indicate that approximately 14,000 managerial and clerical staff and 4,500 construction professionals will be required each year up until 2006 in order to account for the forecasted market expansion (CITB, 2002). The low numbers of undergraduate entrants into the industry raises fundamental questions as to whether these levels (that is, those cited by the CITB) will be achieved and hence, the likely future prosperity of the civil engineering profession. In the short-term, the sharp decline in admissions could force employers to recruit from other engineering disciplines, or even retrain non-cognate graduates in order to meet their labour requirements. Furthermore, as competition increases for the

dwindling numbers of graduates that are available, increasing pressure will be exerted upon construction firms to either raise the starting salaries of those who are available and provide additional employment incentives. Indeed, United Kingdom civil engineering graduate salaries have already increased dramatically in recent years as the civil engineering industry skills shortage has taken effect (Hansford, 2001).

The longer-term impact and severity of the marked decline in recruitment to undergraduate civil engineering courses remains uncertain. However, most reports and industry commentators suggest that it will negatively effect the future competitiveness and capacity of the industry. For example, the water, road, railways and nuclear energy sectors have all expressed concerns that without the rapid injection of suitably equipped personnel, consultants and contractors will fail to cope with future workload (Mylius, 2001). Falling numbers of civil engineering students are expected to militate against the ability of consultants and clients to gear up for the massive transport growth that is expected over the next decade. This could in turn undermine the Government's delivery of its 10-year transport plan (Oliver, 2000). The decline in the popularity of civil engineering courses could also impact on the industry's need to improve its performance in line with the demanding targets set out within the *Accelerating Change* reports (Strategic Forum, 2002).

Surprisingly, Byfield's (2001) analysis of admissions statistics also reveals that the quality of entrants has actually improved in recent years. Byfield found no evidence of falling standards measured by the entry qualifications of United Kingdom undergraduates since 1996. This finding is contrary to other reports on the quality of civil engineering undergraduates, where concerns abound of falling standards and the increased efforts having to be used by academic departments to address them. For example, according to one recent report, three in 20 students are failing to complete courses (half of whom drop out because they cannot cope with the workload or subject matter) and some 96 per cent of civil engineering departments say that students' grasp of mathematics is inadequate (New Civil Engineer, 2001a). Thus, the wider implications of the declining enrolment to civil engineering courses currently remains uncertain.

THE NEED FOR FURTHER ANALYSIS

Doubts must remain as to the sustainability of a profession that is witnessing a year-on-year decline in its graduate intake, particularly given the concurrent growth in the sector's output over this period. The industry is currently experiencing its best period of sustained economic growth since the late 1980s, with recent figures illustrating that construction industry output has increased some seven per cent in the year up to the third quarter of 2002 (Construction Forecasting and Research, 2003). There is now an imperative need to establish whether such growth is sustainable given the industry's recruitment difficulties and market buoyancy. Accurate forecasting of skills shortages in civil engineering could give the industry's competitiveness a better long-term outlook (Hibbert, 1999). Such knowledge would allow the industry and its professions to target its recruitment activities more appropriately in the future.

Although the reporting of rudimentary statistics have demonstrated a steady decline in civil engineering applications and enrolments since the early 1990s, a predictive model for forecasting the likely severity of the decline has yet to be developed. Such a model could inform the civil engineering profession, its employers and university departments of the likely future severity of the decline, and therefore help to promote the *prima facie* case for taking drastic action to arrest the impact of such. In pursuance of this aim, this paper presents an analysis of university admissions statistics and uses these data to develop a predictive model for forecasting the likely severity of future graduate shortfalls. To put this decline into context, the analysis is compared with civil engineering economic output over the same period. By contrasting graduate intake with sector turnover, the paper explores whether there is any correlation between market buoyancy and the attractiveness of a professional civil engineering career.

Further, more exhaustive, commentary on the current situation is provided by a desegregation of male and female enrolments to civil engineering courses over this period. Subsequent analysis of these dichotomous groups sought to establish whether initiatives to attract women to the engineering professions have had any impact in addressing the current paucity of civil engineering graduates. In total, these analyses should prove valuable in understanding the severity of the graduate shortage issue and moreover, establish the potential reasons for the decline in recent years.

METHOD OF INQUIRY

In order to explore trends in application and admissions to civil engineering degree courses, data were collected from the University Central Admission System (UCAS) of applications and enrolments to all building degree courses under the 'H2' classification (civil engineering). Data are presented for a seven-year period from 1994-2001. This reflects the period for which such statistics have been collected by a single admissions body, thereby ensuring the consistency of the figures presented. Data for 1994-2000 were used for the model building and analysis process, while applications data for 2001 were held back and used the test predictions made, for that year. The use of a hold out sample allows the model's accuracy and robustness to be tested.

Having collected reliable student application data, a two-stage analysis process commenced. The first stage involved summary statistical analysis and manipulation of the data in order to explore and report upon any obvious trends that help to select an appropriate modelling technique. Data manipulation was required to produce a so-called 'relative movement' of student applications; the underlying trend when compared to micro economic activity. To achieve this, each year's cohort of students was transposed into a relative index, where the base year (1994) had a value of one. To facilitate a reliable comparison to be made, total civil engineering output (billions of Euro at 1998 prices) were also converted into a relative index. Next, the data collected in the first stage were used to develop accurate models that would facilitate reliable predictions to be made. These were then tested using the mean percentage error (MPE) to determine the accuracy of predictions made for the series used. The forecast for 2001 was then tested using the hold out data and a measure of predictive accuracy made. Model predictions would then allow the following hypothesis to be tested:

United Kingdom civil engineering degree courses are in decline as observed by the reducing number of undergraduates attending courses despite consistent micro economic activity.

THE SIGNIFICANCE OF THE DECLINE IN CIVIL ENGINEERING ADMISSIONS

The number of applications to 'civil engineering' courses for the years 1994 to 2000 is shown in Table 1. The findings show a significant decline in the number of students applying for and entering civil engineering degree courses; from 5,104 applicants in 1994 down to 2,905 applicants in 2000. This represents an alarming 57 per cent reduction in the value recorded in 1994. Disaggregating these figures by sex reveals that this observed reduction in student applications has not been totally consistent across both sexes (see Figure 1). The number of women choosing a civil engineering career has fallen steadily from 587 in 1994 to 415 in 1999, albeit there has been a slight recovery in 2000 with 438 applications being recorded. Conversely, the trend for men is more alarming as the number of applicants has plummeted from 4,507 in 1994 to 2,467 in 2000. In 2000, applicants for men accounted for only 64 per cent of those applying in 1994.

Thus far in the analysis, the recorded trend in student applications has shown an apparent reduction. However, the magnitude of this reduction must be measured in relation to the trend in civil engineering output if its true significance is to be established. This is because it is reasonable to hypothesise that applications would be positively correlated with industry demand (and thus

output). Figure 2 presents the relative index of civil engineering output and student applications over the given period 1994 to 2000. This reveals a somewhat paradoxical trend in that as civil engineering output has increased, student applications have decreased substantially. To quantify this apparent relationship, Pearson's product moment correlation coefficient (r) was used, and shows a strong negative correlation (r = -0.65).

Table 1. Key statistics for Civil Engineering (CE)

Year	Male CE		Female CE		CE Applicants		Total CE Output	
	No.	Index	No.	Index	No.	Index	billions Euro*	Index
1994	4,507	1	597	1	5,104	1	13.82	1
1995	3,957	0.87	581	0.97	4,538	0.88	13.41	0.97
1996	3,638	0.80	569	0.95	4,207	0.82	14.09	1.01
1997	3,224	0.71	542	0.90	3,766	0.73	14.79	1.07
1998	2,939	0.65	503	0.84	3,442	0.67	14.40	1.04
1999	2,665	0.59	415	0.69	3,080	0.60	14.21	1.02
2000	2,467	0.54	438	0.73	2,905	0.56	14.41	1.04

* billions Euro at 1998 Prices, 1 Euro = 0.6776

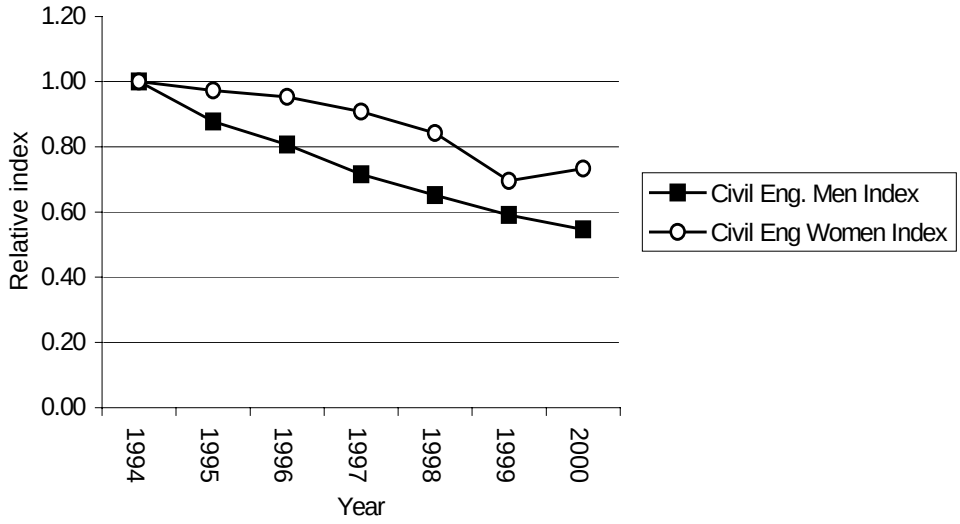

Figure 1. Men vs. Women Applicants

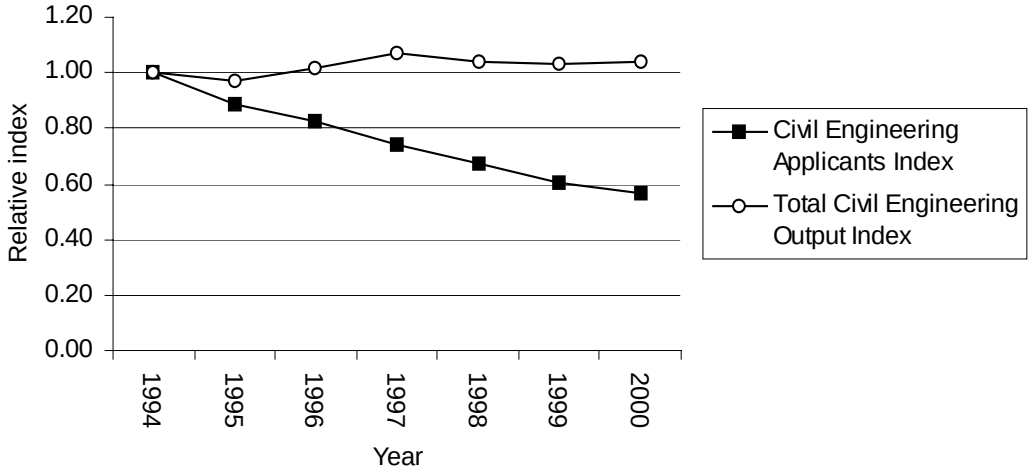

Figure 2. Applicants vs. Output

Modelling of the decline in civil engineering admissions

Previous work conducted by Dainty and Edwards (2003) revealed that the accuracy of the model *per se* was not sufficient to determine a reliable and robust model equation given the limited data available. Dependent upon the data collected, it is possible for the trend to be modelled accurately (in terms of R^2) and yet produce forecasts that are inappropriate and contrary to the trend. To overcome this inherent difficulty with time series analyses, two techniques were employed: the cubic and the quadratic model equations.

Cubic modelling equation

Post preliminary data analysis, data contained within Table 2 was used to model and subsequently, forecast the future trend in civil engineering degree applications. Using the cubic model equation, a good fit of the data was achieved (as demonstrated in Figure 3). The model equation was expressed mathematically as:

$$Y = b_0 + b_1 t + b_2 t^2 + b_3 t^3 + e$$

The model derived was expressed as:

$$Y = 5598.00 + -533.45(t) + 16.2143(t^2) + 0.6667(t^3)$$

Where b_0, b_1, b_2, b_3 are regression coefficients and e is an error term.

Table 2. Model Output

Cubic Model Equation				
Year	Actual Students	Predicted Students	Residual (Error)	MAPE (%)
1994	5104.00	5081.42	22.57	0.44
1995	4538.00	4601.28	-63.28	1.39
1996	4207.00	4161.57	45.42	1.07
1997	3766.00	3766.28	-0.28	0.00
1998	3442.00	3419.42	22.57	0.65
2000	3080.00	3125.00	-45.00	1.46
2001	2905.00	2887.00	18.00	0.61
			Mean Average	0.80
Quadratic Model Equation				
Year	Actual Students	Predicted Students	Residual (Error)	MAPE (%)
1994	5104.00	5085.42	18.57	0.00
1995	4538.00	4597.28	-59.28	0.01
1996	4207.00	4157.57	49.42	0.01
1997	3766.00	3766.28	-0.28	0.00008
1998	3442.00	3423.42	18.57	0.00
2000	3080.00	3129.00	-49.00	0.01
2001	2905.00	2883.00	22.00	0.00
			Mean Average	0.00

To determine the accuracy of the model developed, the R^2 and Mean Absolute Percentage Error (MAPE) (Table 2) values were reported. At 0.998 and less than 1 per cent respectively, the model is proved to be both a valid and reliable predictor of student applications.

Using the cubic model developed, a forecast for the next five years was derived viz:

2001: 2,709.46

2002: 2,596.33

2003: 2,551.63

2004: 2,579.35

2005: 2,683.51

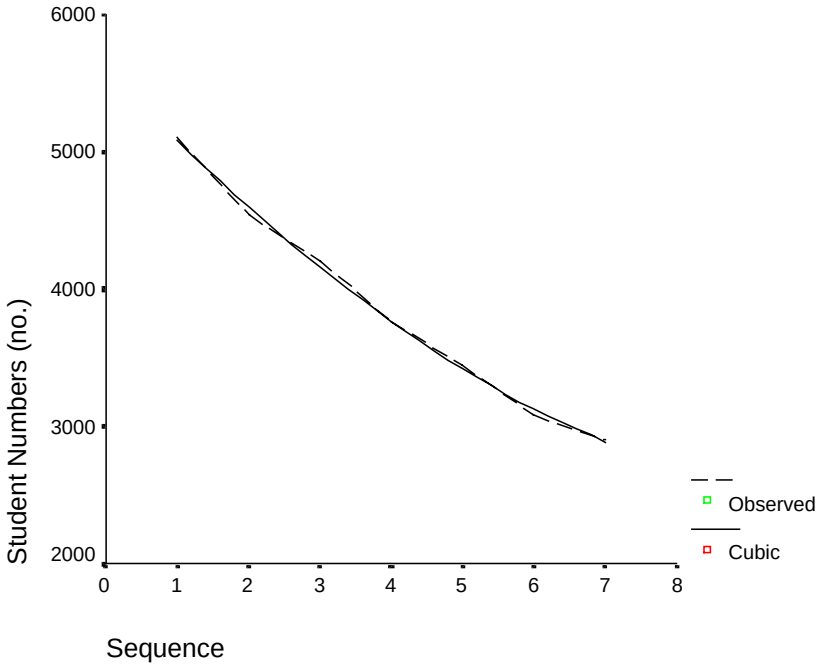

Figure 3. Cubic Model Fit

At this juncture the predicted values seem to remain largely static; albeit there is a slight recovery forecasted for 2004 and 2005. To determine whether this finding is valid, a quadratic model equation was also used to model the data, as shown in Figure 4.

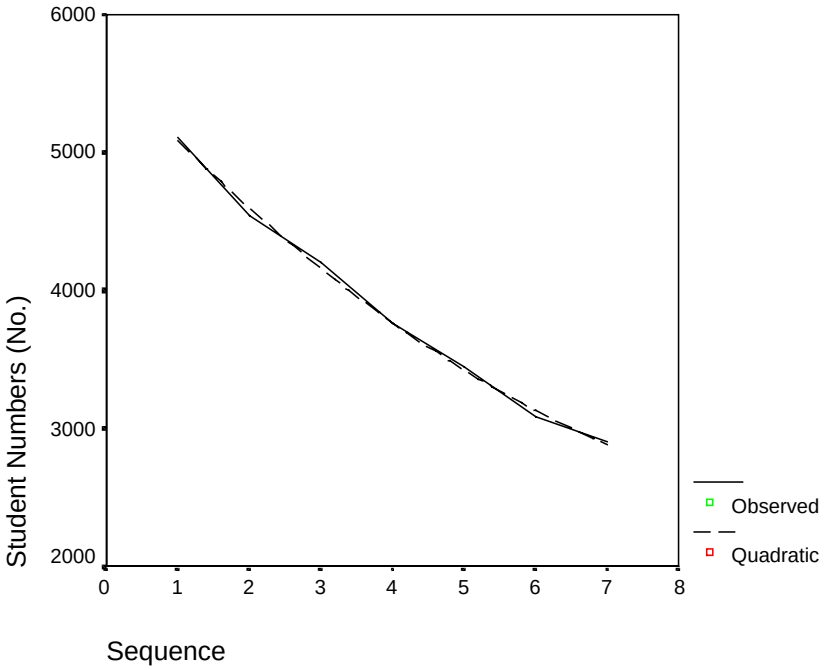

Figure 4. Quadratic model fit

Quadratic modelling equation

The quadratic equation can be expressed mathematically as:

$$Y = b_o + b_1 t + b_2 t^2 + e$$

The model derived was expressed as:

$$Y = 5{,}622.00 + -560.79(t) + 24.2143(t^2)$$

With an R^2 and Mean Absolute Percentage Error (MAPE) value at 0.998 and less than 1 per cent respectively, the model is proved to be an equally valid and reliable predictor of student applications. Using the quadratic model developed, a forecast for the next five years was derived viz:

2001: 2,685.39

2002: 2,536.24

2003: 2,435.53

2004: 2,383.24

2005: 2,379.37

These five values point towards a further gradual reduction in student applications.

Model validation

There is great synergy between both the cubic and quadratic models, in that performance analysis outputs (R^2 and MAPE) are identical. Furthermore the expected change in student applications is not expected to rise significantly over the next two years. Consequently, either modelling equation could be used to produce a reliable forecast. Regardless of the model equation used, the shortage of civil engineering graduates is expected to continue (see Figure 5).

Additional validation work was undertaken by measuring the accuracy of the prediction for the year 2001 to confirm the reliability of the forecasts made. In 2001 2,484 applications were recorded. This figure represents an 8 per cent deviation (approximately) from the prediction forecast for that year. Predictions to within 10 to 15 per cent of the samples are acceptable and prove model reliability (Edwards and Griffiths, 2000). This suggests that the predictions made are both reliable and robust, in spite of the relatively limited number of years for which data were available and on which the models and predictions were based.

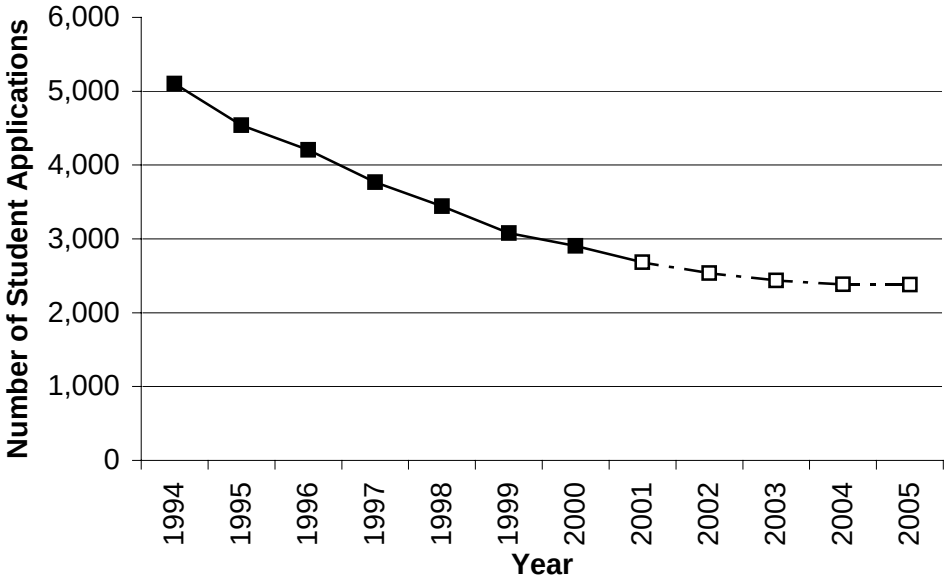

Figure 5. Plotting the quadratic model forecast

DISCUSSION

The preceding analysis provides little in the way of optimism for the civil engineering profession. Despite the industry's sustained growth forecasts for the next few years, forecasts generated by this research suggest an impending recruitment crisis for graduate civil engineers in the medium term (2 to 5 years). Although these findings are alarming in themselves, the situation is likely to be further exacerbated by graduates who decide not to embark upon a civil engineering career upon graduation. For example, civil engineering graduates are often targeted by the comparatively higher paying financial and insurance sectors, which value their analytical education as a foundation for a financial career (Byfield, 2001).

On the basis of the trends identified, it is reasonable to suggest that the declining popularity of the civil engineering profession could impact upon the industry's future development and therefore, effect its future capacity and capabilities in the face of increasing foreign competition. An immediate and obvious implication is likely to be a marked increase in graduate salaries as firms compete for a decreasing cohort of able graduates. Simultaneously, those experienced professionals who are already employed within the sector may be poached by competitor firms who may offer greater fringe benefits and remuneration packages. Spiralling employment linked to tight labour market conditions are ultimately likely to impact upon the cost of civil engineering projects (Agapiou et al, 1995).

There are a plethora of potential reasons as to why the civil engineering profession fails to attract and retain graduates. However, the most significant are likely to relate to the sector's image and its working practices. The industry has a fundamental image problem in attracting high quality school leavers, and especially women and ethnic minorities (Sommerville et al., 1993; Centre for Ethnic Minority Studies, 1999). Construction has an image synonymous with high cost, low quality, chaotic working practices and a poor record for health and safety (Ball, 1988). Engineering job titles have been shown to evoke a fairly low-grade image amongst many lay people (Newman, 1998). In terms of the working environment, the inherent pressures placed upon those working within the industry are known to lead to considerable stress and to the unattractive nature of the sector. Key factors include transient working, low pay, poor working conditions, an unpopular and unprofessional image of the industry and a lack of employment continuity (see Lingard 2003). According to the *New Civil Engineer* (2002b), 75 per cent of engineers feel overworked and 82 per cent feel undervalued. This has resulted in 64 per cent having considered leaving the industry in the last year while 53 per cent actively seek a new position.

Stemming the decline in undergraduate enrolments requires that the civil engineering profession aligns itself with the current moves to improve the future skills prospects of the industry. The CITB migrated towards a more proactive approach dealing with construction skills shortages (Barrie, 1998). These include new advertising campaigns and the National Construction Week initiative, which is now run as an annual industry promotional event. Some civil engineering firms have independently initiated schools recruitment and sponsorship programs to solve their recruitment problems (Cole, 2002).

Non-cognate graduates, who derive from non-civil engineering first-degree disciplines, offer an increasingly necessary potential source of new entrants to the sector. Other sections of industry, such as building construction, have already adopted this approach in order to benefit from a sustainable source of the best graduates. However, this strategy is fraught with problems in that training costs are relatively high, the students' commitment to the industry cannot be guaranteed and while not insuperable, attracting them to the industry has proved problematic. In addition, the entire strategy relies upon industry practitioners offering attractive graduate starting packages comparable to rival professions (for example, law and accountancy). Perhaps unsurprisingly, support has not been widely apparent throughout the civil engineering sector. Given the relative

increase in female applications to the civil engineering courses, another possible idea would be to target resources on non-traditional groups as potential entrants to the profession. Women and ethnic minorities in particular offer a significant untapped resource, and so a possible so-called feminisation of the profession may offer a realistic solution to the industry's recruitment crisis. Such a strategy may also help to improve the poor image of the sector and the careers within it.

CONCLUSIONS

Despite its fundamental significance to the future prosperity of the profession, little statistical analysis has been carried out to explore the severity of the downturn in applications to civil engineering degree courses. Accordingly, this paper has presented an analysis of applications and admissions data with the aim of establishing whether reports of falling numbers and course closures reflect a genuine long-term recruitment crisis for the profession, or merely isolated examples of declining admissions within certain HE institutions. By predicting future trends in graduate recruitment and reconciling these against industry growth forecasts, it has identified whether the current recruitment crisis is likely to impact on the industry's ability to continue to improve its performance.

Based on current projections, the intake of undergraduate students currently entering construction courses will be insufficient to meet the demand over the next few years. The corollary of this is likely to be a future scarcity of civil engineering graduates in the future, and hence, difficulties in recruitment, rising salary levels and perhaps even the threat of foreign competition. Thus, based on the analysis presented, the decline in applications to civil engineering degree courses should be of serious concern to all industry stakeholders.

The civil engineering profession has a proud heritage of providing for the infrastructure needs of the United Kingdom, without which other sectors would not survive and prosper. However, the industry now faces an alarming dilemma in that while an increase in output is apparent, professional candidates, equipped with suitable degrees, are not being attracted to the industry. It is apparent that further reductions in student applications are to be expected, and so immediate action is therefore required to arrest the current trends for the sake of the future prosperity of the industry. These actions should centre on the promotion of the profession as an attractive career, especially to those groups currently underrepresented who provide the greatest potential pool of new entrants. It seems clear however, that the profession has an uphill task if it to reverse the declining interest in civil engineering degree courses.

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